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THE CRANIAL ANATOMY OF THE MAIL-CHEEKED FISHES.

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Introduction.

The mail-cheeked fishes, first grouped together by Cuvier and Valenciennes ('29), are said to be all characterized by the presence of a suborbital stay, that stay being formed by the extension across the cheek, toward or to the operculum, of the third infraorbital bone. In other respects certain families of the group differ greatly from the others, so much so that they have frequently, since Cuvier's time, been widely separated in classificatory schemes. Modern tendency is however to bring the several families together again, Boulenger ('04), the most recent writer on the subject, placing them all in a single division of the Acanthopterygii, which he calls the Scleroparei. Preceding Boulenger, Gill ('88), and, following him, Jordan and Evermann ('98), keep the several families of the group together, but separate them into two suborders, the Loricati and the Craniomi. The latter fishes are said by these authors to be derived from the former and to be distinguished from them, essentially, by the following features only: 1. by the abnormal character of the scapular arch; 2. in that the post-temporal (supra-scapular) forms an integral part of the cranium; and 3. that the postero-temporal (supraclavicular) is „crowded out of place by the side of the proscapula above or at the edge of the post-temporal".

Of the numerous fishes of the group I have had specimens of the following species, and they have all been more or less carefully examined in connection with the present work:

Scorpaena scrofa, S. porcus,
Sebastes dactylopterus,
Cottus octodecimospinosus, C. scorpius,
Trigla hirundo, T. gurnardus, T. lyra, T. pini, T. lineata, T. obscura,
Lepidotrigla aspera,
Peristedion cataphractum, and
Dactylopterus volitans.

The three specimens of Cottus octodecimospinosus and the two specimens of Trigla gurnardus that I have had, were kindly sent me, respectively, by the U. S. Fish Commission Station at Wood's Holl, Mass., and by Dr. Allen of the Plymouth Biological Station, England. Of Cottus scorpius I have had only a few embryos and larvae kindly sent me by Prof. W. C. Mc. Intosh of St. Andrews, Scotland. Of Dactylopterus volitans one of the several specimens was obtained from the Naples Zoological Station. The other specimens used in the investigation were all found in the market here (Menton) or at Nice, and, although they are all Mediterranean species, I have not always been able to satisfactorily identify them; for the features given by Günther ('60) as of specific value are often very variable, and there are apparently, in many of those features, an almost perfect series of intermediate types.

In addition to the investigation of these several mail-cheeked fishes it has been found necessary to carefully examine certain special features in the cranial anatomy of several other fishes, these fishes being mostly obtained here, though certain of them were sent me from America, by one of my assistants, Mr. Wm. F. Allen.

The Scorpaenidae are said by Gill to be the most generalized of the mail-cheeked fishes, and the Scorpaenids to be the most generalized of that family. Because of this, I begin the descriptions with Scorpaena, selecting S. Scrofa because of its being larger than S. porcus. This fish is described with considerable detail, for it is often the apparently unimportant features that are important in comparisons. Each cranial bone is described under its own special heading, and to make the descriptions complete under each of these headings, some repetition has been unavoidable. As the descriptions proceed, comparisons are at once made with fishes other than the mail-cheeked ones, no special sections being devoted to comparative discussions alone. The other mail-cheeked fishes included in the investigation, are, when described, compared, as much as possible, with Scorpaena scrofa only. Scorpaena porcus, the skull of which, though smaller than S. scrofa otherwise closely resembles it, is referred to only where appreciable differences were noticed.

The nomenclature employed differs somewhat from that heretofore employed by me, for it has seemed to me best to adopt, in large part, the current English names of the cranial bones. This will appear in the descriptions of Scorpaena, and needs no special explanation here.

During the investigation, which has been in progress during several years, I have had the continued aid of my three assistants at Menton, Mr. Jujiro Nomura, Mr. G. E. Nicholls and Mr. John Henry, to whom the preparation of the material, the drawings used for illustration and the literature references were largely confided, circumstances obliging me to be frequently absent from the laboratory. The dissections were almost all prepared by Mr. Henry. Mr. Henry also traced the nerve components in the sections of Dactylopterus, controlling also certain of the results obtained by me in the examination of the sections of Scorpaena and Lepidotrigla. The drawings were made by Mr. Nomura from specially prepared specimens, not used for the descriptions, and because of frequently occurring individual variations in different specimens the figures will be found to differ in certain details from the descriptions. The descriptions give the usual conditions.

When the work was nearly finished I received Supino's ('04/06) work on the Triglidae, in which Scorpaena scrofa, Sebastes, Trigla lyra, Cottus, Peristedion and Dactylopterus are all described and figured. But both the descriptions and the figures are so incomplete and so lacking in definite detail that but little reference will be made to them. Garman's ('92) figure of Cottus octodecimospinosus, given in his work on „The Discoboli", is equally indefinite and unsatisfactory.

I. THE LORICATI.

I. Scorpaena.

1. SKULL.

The complete skeleton of the head, and the skull proper (neurocranium) of Scorpaena scrofa are show in Figs. 1—9. As is well known, the orbits are large; the interorbital wall simple; the dorsal surface of the skull, between the orbits, deeply concave and traversed longitudinally by two prominent ridges; and on the vertex there is a subquadrangular groove which is slightly broader than it is long, and which is bounded on either side, and both anteriorly and posteriorly, by ridges.

The two longitudinal ridges between the orbits mark the course, on either side of the head, of the supraorbital latero-sensory canal. Each of these ridges turns postero-laterally at its hind end and is there joined by the transverse ridge that forms the anterior boundary of the groove on the vertex, the single ridge formed by these two ridges united then immediately turning posteriorly and terminating in a pronounced spine. This spine lies not far from the hind edge of the frontal, at the anterior end of the ridge that forms the lateral boundary of the groove on the vertex, and it projects backward, or backward and laterally above the opening of the seventh, or terminal tube of the supraorbital latero-sensory canal, that opening lying immediately lateral to the lateral bounding ridge of the groove on the vertex. Emery ('85) has called this spine the frontal spine, naming it after the bone on which it lies, and I adopt this term rather than the term tympanic, given by Jordan & Gilbert ('83) to the corresponding spine in Scorpaena porcus.

The tympanic spine of the Scorpaenidae, as defined by Eigenmann and Beeson ('94) in their descriptions of the Sebastinae, is said to always overarch a mucous pore, to always lie near the outer border of the frontal, and to be always present and homologous throughout the group. The coronal spine, as defined by the same authors, is said to be developed in but few species, to lie on the frontal, nearer the mid-dorsal line than the tympanic, and directly in front of the parietal ridge. The frontal spine of Scorpaena scrofa thus has the relations to the supraorbital latero-sensory canal of a tympanic spine, while in other respects it has the position of a coronal spine, as that spine is shown both in Jordan & Gilberts' diagram of the cranial ridges of Sebastodes (l. c. p. 653) and in Cramer's ('95) figures of Sebastodes introniger and Sebastodes auriculatus. The relation to the supraorbital canal is, however, so typical that the spine, in Scorpaena, is certainly a tympanic and not a coronal one. It lies at the hind end of the interorbital ridge on the frontal, that ridge thus appearing as a cranial spinous ridge; but this relation of the spine to the ridge, though apparently usual in the group, is not constant, as will appear when the spine is described in Scorpaena porcus.

Slightly mesial to the ridge that forms the lateral boundary of the groove on the vertex, near the middle of its length, and at the anterior edge of the parieto-extrascapular bone, another cranial ridge begins. Running at first parallel to the lateral bounding ridge of the groove on the vertex, this other ridge soon curves latero-posteriorly onto the bounding ridge, near its hind end, and so leaves the groove on the vertex at its postero-lateral corner. It then curves again into the direction of the bounding ridge, here lying posterior to the groove on the vertex, and continues either parallel to and slightly mesial to the line prolonged of the bounding ridge of the groove, or as a direct posterior continuation of that ridge. It soon terminates in a spine, this spine rising from the dorsal surface of the parieto-extrascapular slightly postero-mesial to the central point of the body of that bone, and lying directly superficial to that section of the supratemporal latero-sensory canal that is lodged in the bone. This spine is the parietal spine of Jordan & Gilbert's diagram of Sebastodes, and it lies approximately at the hind end of the parietal part of the parieto-extrascapular bone. The ridge to which the spine is related is then the parietal spinous ridge, and this ridge is not the one that forms the lateral boundary of the groove on the vertex, that ridge being an independent one, without related spine.

Immediately posterior to the parietal spine, or immediately lateral to its base, another cranial spinous ridge begins, and running postero-laterally to the hind edge of the parieto-extrascapular there terminates in the nuchal spine; this spine thus lying at the hind edge of the extrascapular part of the parieto-extrascapular.

Emery ('85), in his figure of the skull of Scorpaena scrofa, shows but a single spine on the parieto-extrascapular, the spine and bone both being called by him, the external occipital.

In the several specimens of Scorpaena porcus that were examined in this connection, the anterior end of the parietal spinous ridge, instead of beginning close to the lateral bounding ridge of the groove on the vertex, begins well within the groove, sometimes even near the middle of the corresponding half of the groove. It leaves the groove at its postero-lateral corner, as in Scorpaena scrofa, but it is much taller, relatively to the lateral bounding ridge of the groove, than in that fish. It thus forms the apparent lateral boundary of the posterior portion of the groove, and the groove has not the evenly subquadrangular appearance that it has in Scorpaena scrofa.

The frontal, parietal and nuchal spines of Scorpaena form the three posterior members of a row of four spines, the anterior member of which is the nasal spine, lying at the hind end of the nasal bone. There is thus, in this row, a spine at or near the hind edge of each of the four dermal elements that form the mesial portion of each half of the dorsal surface of the skull; the four spines forming a mesial row of spines.

The remaining spines of Jordan and Gilbert's diagram of Sebastodes are the preocular, supraocular and postocular, all three of which are found in Scorpaena. The preocular spine of this latter fish lies on the free, orbital edge of the ectethmoid, near its dorso-mesial end, and forms the hind end of a ridge on the dorsal surface of the ectethmoid which runs, from in front, upward backward and slightly laterally. The supraocular and postocular spines rise from the dorsal surface of the lateral edge of the frontal, both lying posterior to the middle point of the orbit, and both of them projecting postero-laterally in the direction of the lateral edge of the frontal.

From the base of each of these three ocular spines, a ridge runs postero-mesially, the three ridges converging, approximately, toward the point where the fourth tube of the supraorbital latero-sensory canal leaves that canal to run backward and mesially to unite with its fellow of the opposite side and thus form the supraorbital, or frontal commissure of the latero-sensory system. The point

where this commissure leaves the main canal lies anterior and slightly mesial to the antero-lateral corner of the groove on the vertex, and the course of the commissure, on either side, is approximately marked by the anterior bounding ridge of the groove. This latter ridge begins at the median opening of the commissure and from there runs antero-laterally, immediately posterior to the commissure, to become confluent with the frontal spinous ridge at the base of the frontal spine, as already described. The frontal and commissural ridges, as well as the three ocular ridges, thus all radiate approximately from the point where the frontal commissure arises from the supraorbital canal. The parietal ridge, also, radiates from this same point; and still another ridge, a slight one, extends from this point, postero-laterally, across the postero-lateral part of the frontal, and leads directly toward but does not quite reach the anterior end of the pterotic spinous ridge, to be later described. There are thus seven ridges radiating approximately from a certain point on the dorsal surface of the skull, all of them apparently in some way related to certain of the cranial spines. But what these relations may be, or what the significance of the ridges, I can not determine, excepting that they would seem to indicate some center of formative action at the point from which they radiate. With the exception of the frontal and parietal ridges they seem not to have heretofore been described. The preocular spine, it is to be noted, has two ridges related to it, one on the frontal and the other on the ectethmoid, the latter being the more important.

In Scorpaena porcus, the comissural ridge runs directly across the hind end of the frontal ridge, this latter ridge abutting against the former one, almost at right angles to it, at a point slightly mesial to the base of the frontal spine and there apparently ending. The commissural ridge and not the frontal ridge thus here bears the frontal spine, the commissural ridge turning sharply backward at its lateral end, and immediately terminating in the backwardly directed spine. This arrangement of ridge and spine is a definite characteristic of all my specimens of Scorpaena porcus, while the former arrangement is equally characteristic of all those of my specimens of Scorpaena scrofa in which there are three postfrontal spines, described below. Where there are, in Scorpaena scrofa, but two of these latter spines, the relations of the two ridges here in question, to each other and to the frontal spine, are intermediate in character.

In addition to the above described spines, all of which are mentioned by Cuvier and Valenciennes ('29, vol. 4, p. 291), there are, on the dorsal surface of the head of Scorpaena scrofa, a certain number of other spines, all of which, excepting two, those on the lateral extrascapulars, are also mentioned by Cuvier and Valenciennes. Three of these spines are small, and lie on the postfrontal bone; one near the antero-mesial corner of the bone, one at the postero-mesial corner and one at the postero-lateral corner. The three spines radiate, in general direction, from the antero-lateral corner of the bone, and on that corner there is a small but pronounced tubercle. Joining this tubercle and the antero-mesial spine there is a small but definite ridge, the other two spines having no related ridges. In Scorpaena porcus, in all the specimens examined, there were in this group of postfrontal spines, but one or two spines; the one spine, where it alone was found, being usually bifid. The presence of the three postfrontal spines thus seems to be a definitive characteristic of Scorpaena scrofa, but in certain of my specimens of this fish there are but two spines, as in Scorpaena porcus. These postfrontal spines must be the bifid spines of Jordan & Evermann's ('98) descriptions.

Postero-mesial to this little group of postfrontal spines, a ridge begins on the pterotic, and running postero-laterally to the hind end of that bone ends in a strong spine. Posterior to, and in the line prolonged of this spinous ridge, a ridge begins on the suprascapular, and running along the

dorsal surface of the lateral edge of that bone ends in a spine that would seem to be the exoccipital of Jordan & Evermann's descriptions. Posterior to this suprascapular spine, and in line with it, the dorsal edge of the supraclavicular ends in a more or less pointed corner, but there is here no regular spine. Between the pterotic spine and the anterior end of the suprascapular spinous ridge, the lateral edge, or the postero-lateral corner, only, of the lateral extrascapular intervenes; and on that corner there is a small sharp prominence, rather than spine. This prominence forms the postero-lateral end of a small ridge which extends, from there, antero-mesially across the dorsal surface of the bone.

These several additional spines thus form a lateral row on the dorsal surface of the skull, one or more of the spines being found on each of the dermal bones that form the lateral portion of the dorsal surface of the skull, the lateral extrascapular excepted. But it is to be noted that the postfrontal spines lie lateral to the anterior end of the pterotic spinous ridge, and that that ridge is continued anteriorly by the slight ridge, already described, that leads toward the point from which the frontal commissure arises from the supraorbital canal.

Between the hind ends of the lateral and mesial rows of spines, there is a short row of two small spines, one on the hind edge of the lateral extrascapular and the other on the hind edge of the epiotic process of the suprascapular.

Considering, now, the posterior portion only of the dorsal surface of the skull, there are seen to be, on each side, four ridges or lines of ridges diverging approximately from the frontal spine. One of these ridges is the commissural ridge, which extends postero-mesially to the mesial edge of the frontal; and another is the postocular spinous ridge which extends almost directly laterally to the lateral edge of the same bone. Between these two ridges are the parieto-nuchal and pterotic ridges, both extending backward, but diverging. These four ridges thus divide the posterior portion of the dorsal surface of the skull of Scorpaena into three regions which are seen to be strikingly similar to the regions occupied by the supratemporal, temporal and dilatator grooves of Scomber (Allis, '03); and the three grooves of Scomber would arise if the three regions in Scorpaena were to undergo a depression, this depression being accompanied by a diminution in size and a backward translation of the lateral extrascapular, and by a separation of the postfrontal from the underlying bones of the skull.

SUBQUADRANGULAR GROOVE.

The subquadrangular groove on the vertex of Scorpaena is a single median depression, which occupies the position of the two supratemporal grooves, united, of Scomber. Laterally it is bounded, on either side, in part by the parietal spinous ridge, and in part by the ridge that runs backward from the base of the frontal spine immediately lateral to the parietal spinous ridge, this second ridge bearing no spine. The anterior edge of the groove is reëntrant, and is formed, on either side, by the corresponding commissural ridge. Posteriorly the groove is bounded by a transverse ridge on the dorsal surface of the supraoccipital, this ridge being heightened by superimposed, transverse suturating processes of the parieto-extrascapulars. The parietal spine lies at the lateral end of this transverse ridge, and hence at the postero-lateral corner of the groove. The frontal spine lies at the antero-lateral corner of the groove. The floor of the groove is formed mainly by the frontal and parieto-extrascapular bones, but a small median portion of the supraoccipital is exposed near the middle point of the groove. These same three bones, on either side of the head, form the floor of the larger, anterior portion of the supratemporal groove of Scomber, the extreme posterior portion of the floor of the groove, in this latter fish, being formed by the supraoccipital and epiotic. The groove, in

Scorpaena, thus seems to represent the fused anterior portions only of the supratemporal grooves of Scomber. The posterior portions of the grooves of the latter fish must accordingly be looked for elsewhere in Scorpaena, and they would seem to be represented, in this latter fish, in two small pockets, one on either side, which occupy what is, in appearance, the dorsal portion of the posterior surface of the skull. The pockets lie on a dorsal, shelving portion of the posterior surface of the skull, this shelving portion being separated from the portion ventral to it by a distinct angle, usually produced into more or less of a ridge. This ridge is transverse and nearly horizontal in position, corresponds approximately to the hind edge of the dorsal surface of the skull of Scomber, and appears as that edge of the skull of Scorpaena when the dermal bones are removed (Fig. 7).

There are thus two hind edges to the supratemporal portion of the dorsal surface of the skull of Scorpaena, an antero-dorsal one formed by the dermal bones, and a postero-ventral one formed by the primary bones. The development of these two edges I have not attempted to investigate, but the space between them evidently represents the extent to which the trunk muscles have invaded the dorsal surface of the skull in the supratemporal region. This supratemporal invasion is distinct from the one that enters the temporal fossa, and its extent, which varies greatly in different fishes, seems to be in some way related to the development of the extrascapular bones and the latero-sensory canals they carry. Where the mesial extrascapular elements are strongly developed, meet in the middle line, or are fused with the parietals, the trunk muscles pass dorsal to the hind edges of the bones and stop when, or before, they reach the commissural canal: while where the bones are feebly developed, or not fused with the parietals, the invading muscles seem to push them apart, to pass forward beneath them and the canal they carry, and then onward, dorsal to the more anterior bones. To the first mentioned, and probably more primitive category belong Polypterus, Amia, Lepidosteus, Dactylopterus, and all those teleosts in which the mesial extrascapular elements have fused with the parietals (Allis, '04); while to the second category probably belong the larger number of teleosts, Scomber being typical of the class. The line that marks, in fishes, the anterior limit of the surface of invasion of the trunk muscles, has been called by Sagemehl ('84b) the linea nuchae, and it forms, in many fishes of the first above-named category, the apparent, and is usually there considered as the actual hind edge of the skull. It is, however, in reality, the secondary hind edge of the skull, the primary hind edge underlying it and being formed by the hind edges of the dorsal surfaces of the primary bones of the skull. The possible presence of these two edges must always be borne in mind, for it is of importance in comparisons of the region.

In Scorpaena, the two little pockets, just above described, accordingly lie on what is probably the posterior portion of the dorsal surface of the skull, and not on its posterior surface. The mesial half of the floor of each pocket is formed by a part of the supraoccipital, the lateral half being formed in part by the epiotic, and in part by the dorso-posterior surface of a flange of bone that projects downward backward and mesially from the ventral surface of the parieto-extrascapular, not far from its hind edge. This flange lies on the dorsal surface of the primary skull, and notwithstanding its apparent origin from the ventral surface of the parieto-extrascapular should probably be considered as a part of the dorsal surface of that bone. The apparent hind edge of the parieto-extrascapular, of either side, projecting backward, forms the roof of the corresponding pocket, and the two pockets are separated from each other by the spina occipitalis. A part of the epiotic, together with overlying parts of the suprascapular and parieto-extrascapular, separate each pocket from the dorsal portion of the corresponding temporal fossa.

TEMPORAL FOSSA.

The temporal fossa of fishes is a hole formed by the more or less complete roofing, by dermal bones, of the temporal groove on the dorsal surface of the primordial cranium. This fossa and groove are both shown in what is considered as the most primitive condition known, in Amia calva, in which fish they have both been described by Sagemehl ('83); but Sagemehl did not recognize, in this fish, an anterior extension, or diverticulum of the groove, to which I later called attention ('89, p. 501), and which becomes incorporated in the groove and fossa in certain other fishes, as shown below.

In Scorpaena scrofa the temporal groove is deep, but short, antero-posteriorly, as compared with that of Scomber, corresponding only to the deeper, posterior portion of my descriptions of the groove in the latter fish. The groove is, in Scorpaena, completely roofed, mainly by the lateral extrascapular and suprascapular bones; but there are, along the edges of the groove, overhanging portions of the pterotic, epiotic and parieto-extrascapular, and between the edges of the parieto-extrascapular and lateral extrascapular, there are narrow spaces spanned by tough fibrous tissue. The groove being completely roofed, becomes a fossa, and opens onto the posterior surface of the skull by a large opening which occupies the dorso-lateral portion of that surface. A small opening between the hind edge of the pterotic and the opisthotic process of the suprascapular, leads into the fossa from the lateral surface of the skull, and through this opening the supratemporal branch of the nervus lineae lateralis, accompanied by certain vagus fibres, passes inward into the fossa. The mesial wall of the fossa is formed by the epiotic; its lateral wall by the pterotic, the opisthotic, and the opisthotic process of the suprascapular. Its floor is formed in part by the sloping side walls of the pterotic and epiotic, but mainly by a relatively wide strip of cartilage which separates those two bones, and which is the temporal interspace of my descriptions of Scomber. Posteriorly this interspace of cartilage is bounded by the dorsal edge of the exoccipital, which bone forms the floor of the posterior opening of the fossa, and, in large specimens, a small part also of the floor of the fossa itself.

The fossa lodges, as in other fishes, an anterior extension of the trunk muscles, and if those muscles were to push forward and upward, through the space covered by the lateral extrascapular, onto the dorsal surface of the skull, they would push forward dorsal to the parietal portion of the parieto-extrascapular and dorsal also to the depressed hind edge of the frontal, and, occupying the region between the mesial and lateral rows of spines, would give rise to the temporal groove of Scomber.

In one specimen, in which the parieto-extrascapular had been removed from the underlying bones, the dorso-anterior end of the temporal groove formed a sort of pocket which is apparently the homologue of the recess in the antero-lateral corner of the groove in Scomber ('Allis, '03, p. 51), and the homologue also of the anterior diverticulum of the groove in Amia. The pocket, in Scorpaena, opened onto the dorsal surface of the primordial cranium by a small and separate opening, which lay immediately anterior to the suturating edges of the superficial portions of the epiotic and auto-pterotic, between those bones and a portion of the chondrocranium, and was covered externally by the parieto-extrascapular.

In the Elopidae and Albulidae, the former of which are said by Ridewood ('04a) to be the most archaic of existing teleosts, and the latter to be in but few respects more highly specialized, the temporal fossa is said to be very extensive. Ridewood calls this fossa the posterior temporal fossa, and says that it extends forward a considerable distance beneath the frontal; apparently extending even

a certain distance between the orbits, for in addition to the proötic, sphenotic (postfrontal, Ridewood) and supraoccipital, Ridewood says that the alisphenoid, and even the orbito-sphenoid form, in one or other of the fishes described, a part of its floor.

Dr. E. C. Starks, of Stanford University, having most kindly sent me two specimens of Elops and a few specimens of Albula, I have examined the temporal fossa in both of these fishes. In Elops, I find that the posterior portion only of the fossa is the homologue of the entire fossa of Scorpaena. This posterior portion of the fossa is much shorter and much less important than the anterior portion, and is separated from the latter portion by a wide and evenly rounded transverse elevation of the floor of the fossa. This transverse elevation, or saddle, separates the fossa into two portions, which have the appearance of having been primarily more or less independent, and only secondarily united to form a single continuous groove. The anterior portion apparently corresponds to the anterior diverticulum of the temporal groove of Amia, the posterior portion corresponding to the temporal groove itself of that fish.

The lateral wall of the posterior portion of the fossa is formed by the pterotic and opisthotic, its mesial wall by the epiotic and supraoccipital, and its floor by the pterotic, the exoccipital, and the temporal interspace of cartilage. In the mesial wall of this posterior part of the fossa there is a deep depression which is certainly the homologue of the preëpiotic fossa of Ridewood's descriptions of Clupea, though that author does not, in Elops, so define it.

The saddle between the anterior and posterior portions of the fossa is formed, in Elops, mainly by the pterotic, the saddle arching over the subtemporal fossa and forming its roof. On the summit of the saddle the layer of bone separating the two fossae is so thin that a slight further excavating of the bone, on either side, would break down the bony separating wall and either put the two fossae into direct communication, or leave them separated by membrane only. This latter condition is said by Sagemehl ('91, p. 555) to be found in Rasbora and Leptobarbus of the Cyprinidae.

The floor and side walls of the anterior portion of the fossa are formed by the pterotic, proötic, sphenotic and alisphenoid, the part of the alisphenoid here concerned being a part of a well developed flange on the internal surface of the bone together with that part of the internal surface of the bone that lies postero-lateral to that part of the flange. This flange of the alisphenoid is continuous ventrally with a ridge on the internal surface of the proötic, this ridge forming the anterior wall of the labyrinth recess. The anterior semicircular canal, running upward and laterally, lies postero-lateral to the ventral portion of the flange, in a recess in the alisphenoid, and, as this recess is bridged by a narrow bar of bone, the dorso-anterior end of the semicircular canal lies in a short canal in the alisphenoid. The sphenotic comes into no bounding relations to the labyrinth recess, being wholly excluded from it and also from all bounding relations to the cranial cavity, by the deep anterior portion of the temporal fossa. If this condition of the sphenotic is primary, its bounding relations to the anterior semicircular canal are evidently a secondary acquisition, and that the condition is primary would seem to be indicated by its being found in this primitive teleost, in Amia, and also in Esox. In neither of these three fishes does the bone extend through the cranial wall; and it accordingly must have been first developed, wholly independent of the anterior semicircular canal, simply to strengthen the post-orbital process of the skull and to give a proper surface of attachment to the muscles that have their origins there. A similar origin is ascribed by Gaupp ('03) to the autopterotic in Salmo.

In the deepest point of the anterior portion of the fossa there is, in the proötic bone, a small circular opening. From this opening a canal runs at first downward in the proötic to the dorsal edge

of the posterior portion of the trigemino-facialis chamber, and then turns backward in the bone, parallel to that edge of the chamber. At the anterior edge of the subtemporal fossa the canal turns inward in the bounding wall of the fossa, still lying in the proötic, and, on one side of the head of the one specimen sacrificed in this examination, there seemed to end blindly at the hind edge of the proötic. On the other side of the head of the same specimen the canal opened into the subtemporal fossa, but whether this opening was an artifact or not, I could not determine. What this canal is I can not determine, but it may, perhaps, be a persisting remnant of the spiracular canal of Amia.

In Albula the temporal fossa is similar to that in Elops, but its anterior portion is much less extensive; and I find no canal opening into the bottom of the fossa. No special description of it seems necessary.

In Esox, according to Vrolik's ('73) figures of transverse sections of the skull, there is, in the temporal fossa, a mesial pocket which has the position of a preëpiotic fossa. The deeper portion of this pocket is bounded both above and below by portions of the supraoccipital bone, exactly as the preëpiotic fossa is, in Elops. The anterior end of the temporal fossa ends blindly in the thick dorso-lateral edge of the chondrocranium, and is there partly surrounded by a thin layer of perichondrial bone which apparently belongs to the pterotic though this is not so stated. The dorsal portion of the alisphenoid is formed by two plates of perichondrial bone, one of which lines the external and the other the internal surface of the cartilaginous cranial wall. The internal plate is apparently raised into a ridge-like process, but whether it bounds a recess for the dorso-anterior end of the anterior semicircular canal, or not, is not evident. The wall of the cranial cavity, however, quite certainly continues backward, in the line of the ridge-like process, until it joins that flange of the supraoccipital that forms the floor of the preëpiotic pocket, as it does in Elops. A region corresponding to that occupied by the anterior portion of the temporal fossa of Elops is thus, in Esox, included in the cranial wall, and the sphenotic, as in Elops, is excluded from bounding relations to the cranial cavity. Assume that there is, on the dorsal surface of this part of the chondrocranium of Esox, an anterior diverticulum of the temporal fossa similar to the one in Amia: a simple enlargement and deepening of this diverticulum, and its partial confluence with the temporal groove of the fish would produce the conditions found in Elops; and if the enlarged diverticulum did not become confluent with the temporal groove, acquiring, instead, an independent opening to the exterior, on the lateral surface of the skull, it would seem as if it must give rise to the conditions described by Ridewood ('04c, p. 473) in Engraulis.

In the Characinidae, judging from Sagemehl's ('84b) descriptions and figures, the pterotic, and that bone alone, forms the floor of the temporal fossa. This is however not true of Macrodon, which I have examined in this connection. In this fish the fossa has anterior and posterior portions, as in Elops, the two portions being separated by a low saddle. The floor of the posterior portion is formed by the pterotic, as Sagemehl states, but that of the anterior portion is formed by the proötic, the latter bone having a widely spreading dorsal edge. The anterior end of the anterior portion of the fossa abuts against and is bounded anteriorly by the sphenotic. The fossa is thus less extensive than in Elops, but much more extensive than in Scorpaena. It has an extensive preëpiotic pocket, and in this pocket lie those fenestrations of the epiotic that are said to be so characteristic of the Characinidae. The anterior wall of the labyrinth recess is formed by a strong flange that lies mainly on the proötic but extends upwards slightly onto the cerebral surface of the sphenotic. Between this flange and the cerebral wall of the anterior portion of the temporal fossa, in a deep groove, lies the anterior semi-

circular canal. In the bottom of the anterior portion of the fossa there is, in my specimen, a foramen — if it be not perhaps simply a defect in the bone — which opens into that canal that leads from the cranial cavity to the upper one of the two apertures called by Sagemehl, in his figures of Erythrinus, the facialis foramina. The opening is so inconspicuous that I should not have noticed it had I not been led to look for it, because of the canal here found in Elops. There are also in my specimen, two perforations of the bony partition that separates the temporal fossa from the dilatator fossa, one of the perforations undoubtedly giving passage to the ramus oticus, and the other probably to a venous vessel similar to the one that, in Scorpaena, accompanies the oticus in its backward course, as will be later described. These several foramina are not described by Sagemehl, and furthermore that author's descriptions of the foramina that perforate the lateral wall of the proötic are certainly not wholly correct. The so-called jugular foramen is found, as shown, opening directly into the labyrinth recess, but this opening in the prepared skull must certainly be closed, in the recent state, by membrane, and hence can not transmit the jugular vein. In the anterior edge of this foramen a small canal begins in the wall of the proötic and, running forward, traverses the base of that flange that forms the anterior wall of the labyrinth recess and so enters a recess of the cranial cavity into which the so-called facialis and trigeminus foramina open. This cranial recess probably lodges, as in Cottus, and as will be fully described when describing that fish, the profundus, communis and lateralis ganglia of the trigemino-facialis complex, the trigeminus ganglion probably having an extracranial position. If this be so, the jugular vein, as in Cottus, does not enter the recess, but lies along the outer surface of the skull immediately beneath the extracranial trigeminus ganglion. One of the two foramina marked „fa" in Sagemehl's figures must then transmit the truncus hyoideo-mandibularis facialis, the other one, said by him to transmit a vein, probably transmitting the encephalic branch of the jugular vein. What the little canal in the proötic that I have just above described transmits, I can not tell, and it may perhaps be an artifact.

In Catostomus teres and Moxostoma sucetta, of the Cyprinidae, the axis of the temporal fossa is said by Sagemehl ('91, pp. 550—553) to lie in a frontal (transverse?) position and the fossa is said to open on the lateral instead of on the posterior surface of the skull. The anterior portion only of the fossa is roofed, the roof there being formed by the mesial edge of the dermal portion of the pterotic, the lateral edge of the epiotic (exoccipitale), and, between those two bones, by a portion of the parietal. In the genus Sclerognathus, the roofing portions of these several bones are said to have almost disappeared, and in the genus Diplophysa to have entirely disappeared; the fossa of this latter fish thus becoming a simple pit or groove on the dorsal surface of the skull, the homologue, apparently, of the groove in Scorpaena, and not of that in Scomber. The extrascapular and suprascapular bones are not here considered by Sagemehl as roofing bones of the groove, but they are nevertheless found in all the Cyprinidae (l. c., p. 507), the extrascapular as a small scale-like bone at the hind edge of the pterotic, and the suprascapular as a long, lance-like bone that lies along the hind edges of the pterotic and epiotic and there roofs the posterior entrance of the temporal groove. In certain others of the Cyprinidae, the temporal fossa is said by Sagemehl to be reduced to a simple and narrow canal which opens on the posterior surface of the skull between the pterotic and epiotic. In the genera Nemachilus, Misgurnus, Cobitis and Acanthophthalmus even this narrow canal is said to become almost entirely obliterated.

A temporal fossa, similar to that of Sclerognathus, is said by Sagemehl to be found in very many of the Physostomi and in nearly all the Acanthopterygii and Anacanthini. This I am inclined

to think is not strictly correct, for the fossa in some of these latter fishes is certainly similar to that in Scomber, which, as above explained, is something more than the equivalent of that in Sclerognathus and Diplophysa. Sagemehl further says that the fossa in the fishes above mentioned has arisen wholly independently of that in Sclerognathus. This also seems to me incorrect. Sagemehl himself says that the fossa in Amia represents a primitive condition. From that fossa, the fossa of Scorpaena is readily and directly derived; and from the fossa of Scorpaena that of Sclerognathus would be directly derived by the simple reduction, which has actually taken place in the latter fish, of the extrascapular and suprascapular bones. And from the condition found in either Scorpaena or Sclerognathus that in Scomber would be produced by the continued anterior prolongation of the muscles that fill the groove, the muscles passing dorsal to the parietal and frontal bones instead of ventral to them. If the muscles passed beneath the parietal and frontal it would give rise to the conditions found in Macrodon and Elops. From the condition found in Sclerognathus, also, that in Nemachilus, Misgurnus, Cobitis and Acanthophthalmus would be derived by a simple constriction of the groove, due to the encroaching ingrowth of the pterotic and epiotic. It seems almost unnecessary to state that the conditions found in these latter fishes is certainly not a primary one, the trunk muscles here being seen in process of excavating the fossa in the solid bones of the skull.

In Gasterosteus, according to Swinnerton ('02), the temporal groove is shallow and wholly uncovered, the extrascapular (supratemporal) being said to lie superficial to the trunk muscles but wholly posterior to the hind edge of the skull. Swinnerton considers the groove in this fish as similar to that in Amia. It is, on the contrary, similar to, but less developed than the groove in Scomber, in which fish the groove also lies wholly external to, instead of internal to, the parietal. A similar groove is also found in all the Clupeoid fishes described by Ridewood ('04c), excepting only Chanos, but there is, in these fishes, a related temporal foramen not found in Scomber or Gasterosteus.

In Gymnarchus the temporal fossa undergoes special development and acquires relations to the auditory organ, as I have recently shown ('04); and, judging from Ridewood's descriptions, the same may be true of the other Mormyridae and of the Notopteridae. In these latter fishes, Ridewood ('04b) does not describe either a temporal fossa or groove, but his figures show such a groove, apparently similar to that of Scomber, this groove being more or less roofed by an extrascapular (supratemporal) bone or bones, and having, in its mesial wall, a large opening. This opening Ridewood describes as a lateral cranial foramen, and he considers it ('04a, p. 61) as the possible homologue of the preëpiotic fossa of his descriptions of Clupea.

In Gonorhynchus, according to Ridewood ('05 b), there is no suggestion, even, of a temporal groove; but, judging from the figures given, it would seem as if there might there be a very shallow groove of the kind found in Scomber.

It may here be stated that, in Notopterus, Ridewood says that the extrascapular (supratemporal) „does not carry the sensory tube", the supratemporal cross-commissure lying anterior to that bone. Bridge ('00, p. 517) however says that this sensory canal of Notopterus is „strengthened", along its lateral and inner walls, by „two longitudinally arranged, thin, semi-cylindrical bones, or sensory ossicles"; which ossicles must accordingly be, or belong to, the extrascapulars. Be this as it may, the variation seems morphologically unimportant, for the extrascapular does not actually „carry" the canal in Gymnarchus either, the bone lying wholly superficial to the canal.

DILATATOR FOSSA.

The dilatator fossa of Scorpaena is a small pit that lies directly above the interval between the two articular facets for the hyomandibular, near the dorso-lateral edge of the skull. Its posterior portion is enclosed in the pterotic, its anterior portion in the sphenotic. Between these two bones there is, in the lateral edge of the roof of the fossa, an interval, which leads onto the roof of the primordial cranium but is covered by the purely dermal postfrontal bone. The fossa gives origin to a small superficial bundle of the dilatator operculi muscle, and corresponds to the deeper, posterior portion, only, of the large dilatator groove of my descriptions of Scomber. If the dilatator muscle were here, in Scorpaena, to push upward through the interval between the pterotic and sphenotic, it would lift the postfrontal from the dorsal surface of the primordial cranium, and occupying the region between the pterotic and postocular spinous ridges, give rise to the dilatator groove of Scomber.

In the bottom of the fossa there are two openings. The anterior one opens directly into the oticus canal and transmits a vein which is associated with the ramus oticus. The other transmits a vein that comes from regions median to the oticus, between the primary skull and the overlying dermal bones.

The dilatator fossa and groove of the nomenclature here employed are the lateral temporal fossa or groove of Ridewood's recent descriptions of the teleostean skull. But Ridewood does not call attention to the marked difference between these fossae and grooves, as just above set forth, and doubtless did not recognize it. In both Elops and Megalops, for example, the lateral temporal groove of Ridewood's descriptions would seem to be the homologue of the dilatator groove of Scomber; while in both Albula and Bathythrissa, the lateral temporal fossa would seem to be the homologue of the dilatator fossa of Scorpaena; the lateral temporal grooves and lateral temporal fossae of his descriptions then not being equivalent.

In the Clupeidae, there would seem to be, from Ridewood's descriptions, a dilatator groove similar to the groove in Scomber.

MESETHMOID.

The mesethmoid has a keel-shaped anterior portion, the keel directed dorsally, and a thin tapering posterior portion which is concave longitudinally, on its dorsal surface, and ends posteriorly in a point. Between these two portions, and at about the middle of the length of the bone, two stout prong-like processes arise, one on either side, and project upward and slightly laterally and forward. The hind edge of each process is usually slightly convex, curving upward, forward and laterally, while the ventral half of the anterior edge is slightly concave; the whole process having the appearance of a horn projecting upward, forward and laterally but with the point cut off obliquely, so that a flat surface is presented almost directly forward. This flat surface gives origin to the ethmo-maxil lary ligament, while the lateral surface of the process gives support and attachment to the hind end of the nasal bone. This stout and prominent process has long been known and is the homologue of the quite differently appearing dorso-lateral process of my descriptions of Scomber, a fact I did not recognize when describing that fish. It has been called the mesethmoid process in certain descriptions of the Scorpaenidae, a name which I adopt as much preferable to the term employed by me.

The median keel on the dorsal surface of the anterior portion of the mesethmoid forms the thick but low internasal wall of the skull. It extends backward a varying distance between the two mesethmoid processes, and on it the cartilaginous rostral slides backward and forward, the tapering hind end

of the cartilage passing wedge-like between the processes and its backward motion being arrested by its wedging in between them. That part of the mesethmoid that lies on either side of the median keel, forms part of the floor of the nasal pit, but the nasal sac rests but little upon it, being crowded off it by the rostral. On the dorsal surface of the posterior portion of the mesethmoid, on either side, the frontal rests, the articulating edges of the two bones being often more or less dovetailed together. The frontal of either side extends forward to the base of the corresponding mesethmoid process, the two frontals entirely covering the posterior part of the mesethmoid excepting only a small median portion.

The mesethmoid of Scorpaena, although undoubtedly a so-called primary bone, consists of two distinctly different portions. One of these portions is a thin dense layer of superficial bone. The other portion is a deeper one, of quite different appearance, which underlies the central portion only of the superficial portion, and there replaces portions of the cartilage of the skull. I have made no attempt to study the development of these two components of the bone, or even to determine, other than most superficially, their character. The investigation has however involved the examination of several series of sections of specimens from 45 mm to 55 mm in length, and in these sections the condition of several of the cranial bones was more or less carefully noted. In these specimens the deeper portion of the mesethmoid of the adult, the portion that replaces parts of the cartilage of the skull, has not yet begun to develop. The superficial portion of the bone is represented by a thin plate that lies closely upon the cartilage of the skull, without intervening membrane, and must be primarily wholly of perichondrial origin; but this perichondrial plate receives, at certain places, accretions, or additions, to its outer surface, and these accretions, although they present in sections exactly the same appearance as the perichondrial plate, seem to be of purely membrane origin. This is particularly noticeable, in my specimens, along the lines of the articulation of the mesethmoid with the frontals, and in the mesethmoid processes. These latter processes rise from and are directly and unbrokenly continuous with the layer of perichondrial bone, but they are so important, and so wholly out of all relation to existing cartilage that they must be largely of purely membrane origin. Otherwise, there must be here an important fold in the perichondrial tissues which occupies the place of a cartilaginous process found in other earlier forms, and this tissue must give origin to perichondrial bone without the related development of any cartilage.

The superficial portion of the mesethmoid of the adult, of dermo-perichondrial origin, as above explained, is in direct contact, on either side, with a corresponding portion of the ectethmoid. Anteriorly it is in contact with the dorsal limb of the vomer. The deeper part of the mesethmoid, of endosteal origin, is every where in contact with, and replaces portions of the antorbital cartilage, and does not extend ventrally through that cartilage.

ECTETHMOID.

The ectethmoid, on either side, is the prefrontal of many authors, the parethmoid of Swinnerton's descriptions of Gasterosteus, and the preorbital ossification of my own descriptions of Amia and Scomber. It has, in Scorpaena, a dragon-wing-like appearance, and consists of a wing, an arm that bears that wing, and a small bit of shoulder or body that bears the arm and supports the mesial edge of the wing. The wing is a thin plate of bone, concave posteriorly and convex anteriorly, which projects upward and backward, in a curved line, from the dorsal surface of the arm, and is fused in the basal portion of its mesial edge with a part of the body of the bone. The wing of the bone develops without being

preformed in cartilage, resembling, in this, the mesethmoid processes of the mesethmoid; but, as in the case of the latter processes, the bone is perhaps of perichondrial origin, developed, in that case, in perichondrial membrane, but without the related development of cartilage. The arm of the bone projects antero-latero-ventrally from a relatively small ossification of the side wall of the skull, this ossification lying immediately in front of the orbit and forming the body of the bone. From the ventro-mesial corner of the anterior surface of the wing, where the arm and wing join the body of the bone, two ridges start, and diverging slightly run upward and backward to the dorso-posterior edge of the wing. The lateral one of these two ridges terminates in the preocular spine, which lies near the dorsal end of the lateral edge of the entire bone. The mesial ridge does not terminate in a spine, but gives support, along its mesial surface, to the lateral edge of the anterior end of the frontal, a pronounced ridge, formed by the two bones, here appearing on the dorsal surface of the skull. The curved lateral edge of the wing turns sharply forward, at its ventral end, to join the outer end of the arm of the bone, a sharp corner, but not a spine, marking this angle in the edge of the wing. In certain of the Scorpaenidae there is said to here be a short, blunt spine. On the dorso-anterior surface of the wing, lateral to the preocular spinous ridge, there is sometimes an eminence, or short spine, which occupies the position of a stout process found on the bone of Cottus, that process there giving support to a lateral process of the nasal bone, as will be later described.

The arm of the ectethmoid is a stout, flat, quadrant-shaped process, which has a slightly curved outer edge presented ventro-laterally, and nearly straight dorsal and mesial edges which are both considerably thickened. The entire arm, in the adult fish, thus looks like two stout processes that arise from a single point, and, diverging, are connected by an intervening portion of thinner bone. In 45 mm specimens the two process-like portions of the arm are of cartilage, enclosed in perichondrial bone, the thinner intervening portion being of bone similar to that that forms the wing of the bone. In the adult, one of the process-like portions of the arm lies in a nearly horizontal position, directed laterally and slightly forward. It forms the dorsal edge of the entire arm, and its dorsal surface forms part of the dorsal surface of the entire skull. Its anterior surface is slightly concave and forms the latero-posterior and part of the posterior wall of the nasal pit. Its outer end is considerably thickened and forms a large articular head, capped with cartilage, which is presented latero-ventrally and but slightly anteriorly, and gives articulation to an articular facet on the dorsal edge of the lachrymal. The other process-like portion of the arm forms no part of the bounding walls of the nasal pit. It is directed almost directly ventrally, and its ventral end forms a small elongated articular head, capped with cartilage, which gives articulation to the posterior ethmoid articular surface of the palatine. Between these two articular surfaces, the outer edge of the arm of the ectethmoid is thin, slightly concave, and not capped with cartilage.

The body of the ectethmoid is an ossification of the ventro-lateral corner of the antorbital process of the chondrocranium, and consists, as the mesethmoid does, of a superficial layer of dense dermo-perichondrial bone, which overlies, but projects everywhere beyond, a deeper endosteal portion which replaces portions of the cartilage. This body of the bone is of less important dimensions than the part that I have described as its arm. It extends but slightly posterior to the point of origin of that arm, but its anterior portion projects considerably anterior to the arm, is gutter-shaped, and embraces the thin lateral edge of this part of the antorbital cartilage. The rounded lateral surface of this anterior portion of the body of the bone is slightly concave, longitudinally, and a deep rounded angle is thus formed between itself and the concave anterior edge of the horizontal, process-like portion

of the arm of the bone. The space enclosed in this rounded angle is further bounded, latero-anteriorly, by the dorsal edges of the lachrymal and palatine, a large oval or rounded passage thus here being formed, between these several bones, which leads from the dorsal to the ventral surface of the skull immediately lateral to the nasal region.

On the dorsal surface of the skull, the mesial edge of the superficial, dermo-perichondrial portion of the body of the ectethmoid is serrated and articulates, by suture, with the corresponding portion of the mesethmoid, the two bones forming the floor and mesial wall of the nasal pit. On the ventral surface of the skull the body of the ectethmoid everywhere lies directly upon or is in synchondrosis with the antorbital cartilage, and is there overlapped externally, along its mesial edge, by the lateral edge of the parasphenoid. Anteriorly, on the dorsal surface of the skull, an interspace of cartilage separates the body of the ectethmoid from the dorsal limb of the vomer, this interspace being bounded mesially by the mesethmoid. On the ventral surface of the skull, in small and even medium-sized specimens, this same interspace of cartilage intervenes between the anterior portion of the body of the ectethmoid and the postero-laterally presented lateral edge of the body of the vomer; but in large specimens, the interspace may be cut into two portions by the backward growth of a process of the vomer, this process meeting or even overlapping externally the anterior edge of the ectethmoid. The lateral edge of the interspace turns slightly upward, and may present an angle, which then forms a prominence on the lateral edge of this part of the skull. The lateral portion of the ventral surface of the interspace, the part that lies lateral to the process of the vomer, when that process exists, is presented ventrally and slightly latero-posteriorly, and gives articulation to a small articular surface at the base of the maxillary process of the palatine. In Scomber, I described this articular surface of the ethmoid cartilage as the ventro-lateral, or septo maxillary process of the mesethmoid, it being the mesethmoid instead of the ectethmoid that, in Scomber, forms its principal support. In most current descriptions of the teleostean skull, it is called the anterior palatine, or prepalatine articular surface or process, the articular surface on the outer end of the ventral process-like portion of the arm of the ectethmoid being called the posterior palatine or postpalatine articular surface or process.

The posterior surface of the ectethmoid forms the concave anterior wall of the orbit; the wing, the arm, and the body of the bone all contributing to it. At the anterior end of the orbit, and somewhat above its floor, there is a pit-like depression, lying partly in the body of the ectethmoid and partly in the adjoining cartilage. The pit gives insertion to the oblique muscles of the eye, and is accordingly the anterior eye-muscle canal. In it, close to its lateral edge, is the posterior opening of the olfactory canal through the antorbital process, that canal being entirely enclosed in the body of the ectethmoid. Immediately lateral to the pit, a strong ligament has its origin, as in Scomber, and running downward is inserted on a transverse ridge-like process of the palatine cartilage that forms the hind edge of the posterior ethmoid articular surface of that element. This ligament is thickened at either edge, thus seeming to represent two ligaments incompletely fused with each other.

Ridewood says ('04a, p. 56) that the ectethmoid (his prefrontal) is usually formed by the fusion of originally separate ectosteal and endosteal components, and he says (l. c., p. 39) that the bone is „purely ectosteal" in Elops. As, in my work, I have never found a dermal ectethmoid, I have examined Elops carefully in this connection, and the bone, in my specimens, is certainly similar to the bone of Scorpaena: that is, it is formed of a perichondrial layer that has acquired dermal accretions, and these accretions do not represent a separate dermal component that has fused with an underlying perichondrial one. That an independent and purely dermal ectethmoid, related to an underlying

endosteal bone, may have existed in earlier fishes, I can not contest, but I greatly doubt it; the apparently dermal prefrontal described in certain fishes belonging, in my opinion, to the frontal or nasal series and fusing with one or the other of those bones and not with the ectethmoid.

VOMER.

The vomer caps the pointed anterior end of the antorbital cartilage, and has dorsal and ventral limbs, one of which forms part of the dorsal, and the other part of the ventral surface of the anterior end of the skull. The anterior edge of the bone has the shape of a broad V, the point of the V directed forward in the middle line; and on the ventral surface of this edge of the bone there is a narrow raised surface the anterior portion of which is garnished with small villiform teeth, the band of teeth passing uninterruptedly from one side of the head to the other. This part of the vomer forms the head of the bone. Posterior to this head, the ventral limb, or body of the bone projects backward along the ventral surface of the skull as a thin plate which tapers rapidly to a sharp point. In its anterior portion, the body of the bone lies against the ventral surface of the antorbital cartilage, while posteriorly it fits into a depressed region on the ventral surface of the parasphenoid. The bone has no pronounced lateral processes, such as are found in Scomber, but in the angle between the head and the body of the bone, on either side, there is a slight process which projects toward, and in large specimens may even come in contact with, the anterior end of the ventral plate of the corresponding ectethmoid. This little process has already been referred to, when describing the ectethmoid, this latter bone and the process of the vomer both growing toward and giving support to the anterior palatine articular process of the ethmoid cartilage. Immediately anterior or antero-mesial to this slightly developed lateral process of the vomer, on the ventral surface of the bone, and slightly posterior to the raised portion that bears the villiform teeth, there is a large but shallow depression which gives origin to a strong ligament, the vomero-palatine ligament, which has its insertion on the mesial surface of the palatine.

On the dorsal limb of the vomer there is a median ridge which forms an anterior prolongation of the median ridge on the mesethmoid. A median interspace of cartilage intervenes between the two bones and extends forward a variable distance in a median slit in the hind edge of the dorsal limb of the vomer, this slit separating this limb of the vomer into two parts which may be called the right and left ascending processes of the bone. Near the hind end of the interspace of cartilage, and immediately in front of the mesethmoid, there is a marked angle in the mid-dorsal line of the cartilage, this angle lying not far from the middle of the entire internasal ridge. On either side of the median ridge, there is, on the dorsal surface of each ascending process of the vomer, a depressed region, and in the line of the bottom of this depression, near the anterior edge of the bone, there is a slight eminence which is found much more developed in the Triglidae. With the lateral surface of this eminence, and in the depressed region posterior to it, the postero-ventral portion of the ascending process of the maxillary articulates, as will be later described.

The ascending processes of the vomer are each in sutural contact, posteriorly, with the anterior end of the perichondrial portion of the mesethmoid; and this posterior portion of these processes has, in the adult, strikingly the same appearance as the adjacent perichondrial portions of the three ethmoid bones. The vomer can, however, be removed from the skull, in slightly macerated specimens, without apparently injuring, in the least, the underlying cartilage. Whether, because of this, the entire bone should be considered as of purely membrane origin, or not, I can not decide; but it would

seem as if it might be partly of perichondrial origin, this perichondrial portion of the bone lying directly upon the underlying cartilage but not yet having acquired endosteal relations to it. In certain specimens, as seen in Figure 10, a bit of cartilage is enclosed in the vomer, near its anterior end, this seeming to indicate that this part of the bone is of perichondrial origin and has surrounded and isolated a bit of the chondrocranium. In sections of young specimens the ascending processes of the bone lie closely against the cartilage but are separated from it by a line of tissue, and this tissue is certainly not a simple perichondrial membrane. Just what it is, I have not sufficient histological experience to determine, but the bone, if by origin a purely membrane one, is certainly here in process of acquiring that direct perichondrial contact with the underlying cartilage that Schleip ('04, p. 351) describes in 29 mm larvae of Salmo. But there is in Scorpaena, even in the adult, no indication of that calcification of the cartilage found in Salmo. It can, however, be positively asserted that the dorsal limb of the vomer, not only of Scorpaena but probably also of all other fishes in which it is developed, has, or may acquire quite different relations to the underlying cartilage than that part of the bone that lies upon the ventral surface of the cartilage and is developed in the mucous membrane of the mouth. And this apparently different origin and character of these two parts of the bone is of importance in the homologies that I shall now seek to establish.

Beginning with Scomber, the two stout condylar processes of the head of the vomer of that fish are evidently the homologues of the ascending processes of the vomer of Scorpaena, the external surface of the processes of Scomber being presented laterally forward and but slightly upward (Allis, '03, p. 68), while in Scorpaena it is presented dorsally; and in Scomber, as in Scorpaena, these processes of the bone seem to be in process of acquiring primary relations with the underlying cartilage. The cartilaginous interspace of the internasal ridge of Scorpaena, partly enclosed as it is between the two ascending processes of the vomer, is thus the homologue of the beak of my descriptions of the chondrocranium of Scomber, and hence of a part of the prenasal process of the chondrocranium of Amia.

In Amia, the so-called posterior process of the premaxillary is, as will be later shown, the probable homologue of the articular process, to be later described, of the premaxillary of Scorpaena. It lies directly upon the dorsal surface of the anterior end of the chondrocranium, and also upon the dorsal surface of the preëthmoid (septomaxillary) bone (Allis, '98); and the anterior, or proximal end of the maxillary articulates with its ventral surface, and also with the anterior edge of the preëthmoid. The vomer lies immediately ventral to the articular end of the maxillary, and, immediately posterior to that bone, against the ventral surface of the preëthmoid. The lateral edge of the preëthmoid encroaches upon the anterior end of the single palatine articular ridge of the ethmoid cartilage, and supports, rather than forms part of, that ridge. Taking all these facts into consideration, it is evident that the preëthmoid of Amia replaces functionally the ascending process of the head of the vomer of Scorpaena, and that if it were to fuse, in Amia, with the underlying vomer, and the vomers of opposite sides were to fuse with each other, a bone functionally the equivalent of the vomer of Scorpaena would arise. But the preëthmoid of Amia is a perichondrial bone that has acquired endosteal relations to the underlying cartilage, while the ascending processes of the vomer of Scorpaena are either purely membrane bones that seem to be in process of acquiring perichondrial relations to the underlying cartilage, or are, perhaps, partly of perichondrial bone that has not yet acquired endosteal relations to the related cartilage. This difference in the character of the bone in the two fishes may however simply indicate that the primary bones develop in a somewhat different manner in Amia and teleosts, being perhaps formed, in Amia, by direct ossification of the cartilage, while in

teleosts the cartilage is usually first broken down and then replaced by bone developed in relation to perichondrial plates. Be this as it may, the preëthmoid of Amia and the ascending processes of the vomer of teleosts seem to be developed in relation to the same region of the chondrocranium, and this seems sufficient to establish an homology.

In Esox, the preëthmoid, bone 3 of Huxley's ('72) descriptions, is an ossification of the posterior edge of that abruptly widened portion of the anterior end of the ethmoid cartilage that Swinnerton ('02) calls the preëthmoid cornu. This ossification, in young specimens of Esox, I find formed of two thin plates of perichondrial bone, united by a thick outer edge of similar appearance, the two plates lying one on the dorsal and the other on the ventral surface of the chondrocranium. In older specimens ossification extends into the cartilage, beween the two plates, from the outer thickened edge of the bone. A lateral corner of the anterior end of bone 2 of Huxley's descriptions lies directly upon the dorsal surface of the preëthmoid; and on the free, latero-posterior edge of the preëthmoid there is a longitudinal articular head, capped with fibro-cartilage, which articulates with a facet on the mesial surface of the anterior end of the palatine. The maxillary bone articulates, by a condylar surface near its anterior end, with a facet on the anterior end of the palatine, the pointed anterior end of the maxillary very nearly, but not quite, reaching the preëthmoid and being bound to that bone by tough fibrous tissue. The lateral corner of the anterior end of the single median vomer rests upon the ventral surface of the preëthmoid. The preëthmoid of Esox, which seems unquestionably the homologue of the preëthmoid of Amia, thus has relations to the other bones that are in accord with the supposition that it finds its homologue in the ascending process of the vomer of Scorpaena, and its manner of development seems intermediate between that of the bone of Amia and that of Scorpaena. The vomer of Esox, as is proper where the preëthmoid is an independent bone, consists of a ventral plate only, as in Amia, without a vestige of a dorsal limb.

The only other fishes in which a preëthmoid has been described, so far as I can find, are certain of the Cyprinidae, and Belone acus. In the Cyprinidae, Sagemehl ('91) shows a preëthmoid (septomaxillary) lying on either side of the anterior end of the internasal ridge, and forming part of the dorsal surface of the anterior end of the snout. Antero-ventrally it closely approaches the anterior end of the vomer, that bone having no dorsal limb. The preëthmoids (septomaxillaries) are said (l. c., p. 510) to each lie upon, or in, a cartilaginous process that gives articulation not only to the palatine but also, through the intermediation of a pad of cartilage, to the maxillary. A fusion of the preëthmoids with the vomer would thus certainly here produce the vomer of Scorpaena.

In the Characinidae the preëthmoids are replaced topographically, as well as functionally, by processes of the mesethmoid (Sagemehl, '84b, p. 30), the vomer reaching, on either side, the base of this process, or even forming part of it. The vomer is said to have acquired pronounced primary relations to the skull, and, in Erythrinus, to even form an important part of the internasal septum. The descriptions and figures are however not definite, and it is impossible to tell whether the preëthmoids are absent or have been absorbed by the mesethmoid or by the vomer.

In Belone acus, Swinnerton ('02) says there is a preëthmoid, and he shows it apparently lying on the dorsal surface of the snout, slightly antero-mesial to his prepalatine articular facet and close to the lateral edge of the mesethmoid. Having several specimens of this fish, I have looked for this bone in three of them, but I have wholly failed to find it.

The frontal, in Belone, has a long, thin, anterior prolongation which lies closely upon the dorsal surface of the cartilage of the snout, exactly as a similar process of the frontal does in Esox. The

anterior end of this prolongation approaches, or even overlaps, externally the hind end of the mesethmoid. The lateral portion of the prolongation supports, on its dorsal surface, the mesial edge of the posterior portion of the nasal. The nasal is a relatively large, flat, subrectangular bone, traversed its full length by the supraorbital latero-sensory canal. The posterior portion of the bone forms the roof of the nasal pit. The anterior portion of the bone rests in part upon the dorsal surface of the anterior prolongation of the frontal, in part upon the dorsal surface of the mesethmoid, and in part closely upon the cartilage of the anterior end of the snout: and this anterior portion of the nasal presents the appearance of being composed of an underlying membrane component fused with an overlying latero-sensory component. Be this composition of the bone as it may, the two parts may be referred to, for the present descriptive purposes, as the membrane and latero-sensory components of the bone. The membrane component projects slightly beyond the anterior and mesial edges of the anterior end of the latero-sensory component, there resting upon the cartilage of the snout. Along the lateral edge of the bone this membrane component turns downward, and so forms a lamina-shaped process which projects ventrally along the lateral edge of the cartilage of the snout; and this lamina-shaped process would seem to be the homologue of the process, na' described by Swinnerton on the nasal of Gasterosteus. Its ventral edge extends to, oris even more or less interposed between, the anterior end of the palatine and the cartilage of the end of the snout, this process of the nasal thus seeming to form part of the articular surface for the anterior end of the palatine.

In two of my specimens of Belone the membrane component of the nasal was easily detached, in part or in whole, from the overlying portion of the bone; and although this may have been due to a partial disintegration of the bone, due to the fact that my specimens had been long preserved in alcohol and had then been boiled, it would tend to indicate that the part of the bone that so separated was an independent ossification. It is a strictly and evidently ectosteal bone, and hence can not represent, in any part, the bone described by Swinnerton as the preëthmoid, which bone he classes as „undoubtedly endosteal".

Immediately anterior to the anterior end of the palatine, there is, on the lateral edge of the cartilage of the snout, a small but marked eminence not shown or described by Swinnerton, but which must be the preëthmoid cornu of that author's nomenclature notwithstanding that it forms no part of the articular surface for the palatine. The ventral edge of the laminar process of the nasal reaches the base of this little process, but does not extend upon it; and between the cartilaginous process and the lateral surface of the laminar process, there is a groove which receives the dorso-mesial edge of the maxillary bone, the latter bone articulating in part with the cartilage here, and in part with a small articular surface on the laminar process of the nasal. The maxillary thus here articulates with the dorsal surface of the snout, and, furthermore, partly with an apparently membrane component of the nasal bone, which component thus seems to here replace the preëthmoid, and may perhaps represent that bone. This membrane component of the nasal also somewhat resembles bone 2 of Huxley's descriptions of Esox, and it may be the homologue of that bone and not of the preëthmoid; this then applying also to the process na', of the nasal of Gasterosteus. This needs more careful investigation than I have been able to give it, but it is evident that as the vomer has no dorsal limb, the preëthmoid, if not absent, must be elsewhere represented.

The palatine of Belone is said by Swinnerton to articulate with the cranium at its anterior end only, the posterior articulation being said to be wholly absent. This certainly is not true of my specimens. Here the lateral wing of the antorbital cartilage is not entirely occupied by the ectethmoid

bone, the cartilage extending ventrally beyond the bone, and its ventro-lateral end projecting as a small process which certainly gives articulation to the palatine cartilage at or near its hind end. Between this articular surface and the surface that gives articulation to the anterior end of the palatine, the dorsal edge of the palatine cartilage approaches closely a narrow longitudinal ridge on the ethmoid cartilage, is strongly attached to it by fibrous tissues, and would seem to be in contact with it. The anterior end of the palatine lies against the internal surface of the maxillary, posterior to the articular surface on the dorsal edge of that bone, and posterior also to the little preëthmoid cornu.

Belone, it may here be stated, presents certain peculiarities in the distribution of its latero-sensory canals. There is, in this fish, as is well known, a ventral body line, with a short branch line running upward slightly in front of the pectoral fin. What is not known, so far as I can find, is that there is a canal in the premaxillary, this canal apparently being an anterior and independent section of the infraorbital line, which extends forward, from the base of the bone, through about one third of its length. There is no slightest indication, on the external surface of the premaxillary, of a fusion of latero-sensory ossicles with an underlying tooth-bearing bone; but the evident supposition is that such a fusion has taken place, the latero-sensory ossicles, of either side, together representing the ethmoid of Amia and the supraethmoid of Salmo (Parker, '73), and each ossicle here being fused with the corresponding premaxillary to form the ascending process of that bone. A cartilaginous rostral is held between the hind ends of the premaxillaries, as it is, in Scorpaena and many other fishes, between the ascending processes of those same bones.

A further peculiarity of the latero-sensory system of Belone is, that from the point in the frontal where, in other fishes that I am familiar with, the penultimate tube of the supraorbital canal arises from that canal, the canal in Belone seems to separate into two parts. One of these two parts turns latero-posteriorly, traverses the pterotic, and seems to end at the hind end of that bone. The other part continues posteriorly to the hind end of the frontal, and there runs directly into what seems to be the antero-mesial end of the supratemporal canal, which canal then continues backward as the main canal. If the bone here traversed by the supratemporal canal is an extrascapular bone, as its relations to the canal would indicate, a parietal bone would seem to be lacking. These conditions are so unusual that I am collecting and preparing material for a proper study of them.

Returning now to the vomer, it may be said, that in all cases where an independent preëthmoid bone has been properly identified, the vomer has no ascending processes, and is confined to the ventral surface of the chondrocranium; and that in the Acanthopterygii and Anacanthini, in which fishes a preëthmoid has never been described, the figures and descriptions of the vomer show certainly that it usually has, and it seems probable that it always has, a dorsal limb. In other fishes the descriptions and figures are much too indefinite to warrant a serious attempt at comparison. It may, however, be stated that, in a general way, and so far as can be judged from the rather indefinite existing figures and descriptions, that where the maxillary has the relation to the premaxillary that Sagemehl described as lateral (the maxillary lying as a postero-lateral continuation of the premaxillary), the vomer has no ascending processes, and that where the maxillary has the position described by Sagemehl as posterior (internal) to the premaxillary, the vomer has those processes. The maxillary is found lateral to the premaxillary, according to Sagemehl ('84b, p. 101), only in a few families of the Physostomi, those few families of fishes accordingly probably being the only ones in which the vomer is without ascending processes. The maxillary is, according to Sagemehl, never found toothed excepting in those same few families.

The term „posterior", used by Sagemehl to describe the relations of the maxillary to the premaxillary, is confusing; for while the articular end of the maxillary certainly lies posterior (internal) to the premaxillary, the shank of the bone, in all the fishes of which I have specimens, lies dorso-external (that is, anterior or lateral, as the case may be) to the shank of the premaxillary, this relation of the bones being particularly marked when the shank of the premaxillary has a certain dorsal process which I shall describe as the post-maxillary process of that bone.

The dorsal limb of the vomer of teleosts forms an anterior portion of the more or less developed internasal wall, and it is of membrane, or perhaps partly of perichondrial origin. It accordingly does not present the only two conditions that I formerly ('98, p. 458) found unfavourable to the homologization of the preëthmoid (septomaxillary) of Amia with the vomer bone of mammals.

PARASPHENOID.

The parasphenoid of Scorpaena is a nearly straight bone, with well developed ascending processes near the middle of its length. It has a rounded anterior, and a bifurcated posterior end, and the anterior portion of its ventral surface is grooved, as usual, to receive the posterior portion of the body of the vomer. Anterior to its ascending process there is, on the dorsal surface of the bone, a thin longitudinal median ridge which fits into a corresponding depression on the ventral surface of the chondrocranium. Beginning immediately posterior to the ascending processes, there is also, on the dorsal surface of the bone, a median longitudinal ridge, but this ridge is broad and is grooved on its dorsal surface. Anteriorly this groove is shallow, but posteriorly it deepens gradually, until, near the hind end of the bone, it cuts through it, leaving only two pointed processes, one on either side. The groove forms the median part of the floor of the myodome (eye-muscle canal), the ridge lying between the ventral ends of the proötics, and the cartilage that caps those bones abutting, on either side, against its lateral surface.

Swinnerton says ('02, p. 532) that, in Gasterosteus, the ascending process of the parasphenoid, on either side, lies anterior to the exit of the trigeminus nerve, and that it meets and overlaps a process of the frontal sent down immediately in front of the sphenotic. Because of this position, anterior to the trigeminus foramen, he concludes that the process in Gasterosteus can not be the homologue of the similarly named process in Amia, in which fish it lies posterior to the trigeminus foramen. This conclusion is partly correct and partly incorrect, for the bases of the ascending processes, in the two fishes, are homologous, while the dorsal prolongations of those basal portions are not. The entire process lies, in Scorpaena and Scomber, ventral to the trigeminus foramen, and this would seem to be the usual teleostean relation. In Amia, a dorsal prolongation of this basal portion of the process passes posterior to the trigeminus foramen, comes into contact with the sphenotic, and seems to be in some way related to the spiracular canal. In Gasterosteus, a dorsal prolongation of the basal portion passes upward anterior to the trigeminus foramen, there invading and taking possession of the region occupied, in Amia, by the so-called pedicle of the alisphenoid, which latter bone is said by Swinnerton to be absent in Gasterosteus. This arrangement of the parasphenoid, in Gasterosteus, is apparently exactly similar to that found in Cottus, where the process of the bone comes in contact with the alisphenoid as well as with the ventral flange of the frontal, as will be fully described when describing that fish. Here it need only be said that that part of the alisphenoid of Amia that has been described as the pedicle of the bone, is largely or even wholly absent in certain teleosts, there

being replaced by membrane, which membrane might easily be invaded by outgrowths from a neighbouring membrane bone.

In Gonorhynchus Greyi there is, according to Ridewood ('05 b), a process that would seem to be similar to that of Gasterosteus and Cottus, but somewhat more developed, for it is said to come into contact with the sphenotic (postfrontal, Ridewood) as well as with the alisphenoid.

In Osteoglossum formosum, Bridge ('95) describes two processes on the parasphenoid, one of which would seem to be exactly similar to that of Gonorhynchus; for, although its relations to the trigeminus foramen are not given, it is said to come into contact with both the sphenotic and alisphenoid. Bridge considers this process of Osteoglossum as the equivalent of the processes of Amia, Acipenser and Polypterus; but if, as seems so evident, it is simply an exaggerated development of the processes of Gasterosteus and Cottus, it can not be the equivalent of the process of Amia. It is also not the homologue of the process of Polypterus, as is shown immediately below. Whether it is the homologue of the process of Acipenser, or not, I can not determine from the descriptions and figures that I find of that fish.

The second process of the parasphenoid of Osteoglossum is said by Bridge to grow out of the lateral edge of that bone immediately ventral to the root of the ascending process. It projects laterally and slightly upward, and gives articulation to an articular surface on the dorsal edge of the metapterygoid. It is said to have no parallel in any other teleostean fish, but to be represented in Lepidosteus by what is an essentially similar process. This process in Lepidosteus is fully described in the chapter of this work devoted to the myodome, and that it is the homologue of the process of Osteoglossum seems to me, from the figures of this latter fish, very doubtful.

In Polypterus, according to Traquair ('70), the ascending process of the parasphenoid has not only a horizontal portion, or process, which may perhaps be the homologue of the horizontal process of Osteoglossum, but also two dorsal prolongations. One of these dorsal prolongations is apparently the homologue of the sphenotic prolongation of the process of Amia, the other being still a third prolongation, not described in any other fish, which projects dorso-posteriorly, embraces the facialis foramen, and comes into contact with the so-called opisthotic bone.

PREMAXILLARY.

The premaxillary consists of a curved body, often called the horizontal part of the bone, and three processes which rise perpendicularly to that body. The curved body of the bone ends in a blunt point, and its oral surface is covered, nearly its full length, with small villiform teeth, while on its dorsal surface, and extending its full length, there is a slight groove. The three processes of the bone rise from the ental edge of this groove, and the groove lodges the ventral edge of the maxillary.

One of the three processes of the premaxillary is a thin triangular flange that rises, longitudinally, from the distal half of the body of the bone. It projects upward and postero-mesially, perpendicularly to the body of the bone, lies against the internal surface of the maxillary, and, because of this position, may be called the postmaxillary process of the premaxillary. In certain teleosts this process forms the hind end of the premaxillary, the more distal portion of the bone of Scorpaena being represented, in such fishes, by tough gristly connective tissue. This would seem to indicate that the premaxillary primarily extended only to this process, and it would also seem to in-

dicate that the bone of Scorpaena, up to and including this process, is the equivalent of the entire premaxillary in those fishes in which the maxillary lies, in Sagemehl's terminology, lateral to the premaxillary. This, however, requires investigation.

The other two processes of the premaxillary both arise from the proximal end of the bone, and, in the descriptions of many fishes, are both included under the term ascending process. But one of them only is properly that process, the other being a greatly developed articular process.

The ascending process, properly so-called, is directed dorso-posteriorly, and is a long, thin, pointed, plate-like piece of bone which lies in a plane that crosses obliquely and perpendicularly the extreme proximal end of the premaxillary. Its internal surface is presented ventro-postero-laterally and its mesial and larger part rests upon and is firmly attached by connective tissue to the corresponding half of the grooved dorsal surface of the cartilaginous rostral, its mesial edge touching, throughout nearly its entire length, in the mid-dorsal line, the corresponding edge of its fellow of the opposite side. The external surface of the process is presented antero-dorso-mesially, and so forms, with its fellow of the opposite side, a V-shaped longitudinal groove on the dorsal surface of the anterior end of the snout. This groove is wide antero-ventrally, but tapers dorso-posteriorly to a narrow end. The antero-ventral end of the groove is filled with a pad of tough fibrous tissue which extends downward between the anterior ends of the two premaxillaries and binds them strongly but loosely together. The dorso-posterior end of the groove lodges a similar but smaller pad of tissue, and this pad gives attachment to a stout ligamentous band which here crosses the outer surface of the two ascending processes. This ligament, from here, runs downward and laterally, on either side, passes ventral to the nasal bone, between it and the ethmo-maxillary ligament, and is inserted on the base of the maxillary process of the palatine. A branch of this ligament runs antero-ventro-laterally to the antero-mesial corner of the articular process of the premaxillary and then laterally to the mesial (proximal) end of the ligamentary process of the maxillary, having an attachment at each of these points; while a smaller branch of the ligament runs backward and laterally, and is inserted on the anterior surface of the mesethmoid process. The function of this latter branch of the ligament is evidently simply to fix a limit to that anterior motion of the rostral that accompanies the protrusion of the premaxillaries, the main ligament holding the rostral down upon the dorsal surface of the snout.

The articular process of the premaxillary arises from the bone immediately lateral (distal) to the ascending process. It is a relatively large plate of bone which lies in a plane that begins at the antero-lateral edge of the base of the ascending process, at an acute angle to the plane of that process, and from there runs postero-laterally across the dorsal surface of the body of the bone. At the point where its antero-mesial edge joins the antero-lateral edge of the ascending process, there is a marked but rounded angle in the antero-lateral edge of the latter process. The external surface of the articular process is flat and smooth. On the postero-lateral portion of its internal surface there is a large flat articular eminence which gives articulation to a part of the articular head of the maxillary, in a manner that will be later described.

In an earlier work ('98) I came to the conclusion that the ascending process of the premaxillary of teleosts is primarily an independent bone, and that this independent bone is represented in the median dermal ethmoid of Amia, and probably also in bone 2 of Huxley's descriptions of Esox. This conclusion, in so far as it regards the dermal ethmoid of Amia, seems confirmed by the conditions found in Lophius, Sphyraena, Salmo, Elops, and other fishes that I have been led to examine in this

connection. Regarding bone 2 of Esox I have made no further investigation, but it would certainly seem to be the homologue of the dermal ethmoid of Amia.

In Lophius piscatorius, the premaxillary has a well-developed articular process, but no attached ascending process. At the place where this latter process would normally arise, there is a transverse facet which gives articulation to the anterior end of a long and tapering bone. This is all seen in Bruhl's ('56) figures of this fish, and the long and tapering bone is considered by that author as the detached ascending portion of the premaxillary (infra-maxillary), which it unquestionably is. It lies close against its fellow of the opposite side, the two bones, united, lying in a large rostral chamber on the dorsal surface of the snout. No rostral cartilage is found, but it is quite unquestionably represented in the tissues that envelope and underlie the two bones. The ascending processes of the premaxillaries thus here have a shape and position that render them easily recognizable as those processes, which the dermal ethmoid bones of Amia and Esox have not, and yet, as in these latter fishes, the two bones are wholly independent of the bodies of the premaxillaries.

In Sphyraena vulgaris the premaxillary has both articular and ascending processes. The ascending process rests against the antero-mesial edge of the articular process, wholly free from it, but flexibly and apparently uninterruptedly connected with the premaxillary immediately antero-mesial to the base of the articular process. The connection is by the intermediation of what looks like gristly tissue, and it is evident that a primarily independent bone is here in process of fusion with the premaxillary. That the bone can not be an outgrowth of the premaxillary that is in process of becoming detached from it, seems self-evident.

In Salmo salar, Parker ('73) shows the premaxillary as a large and somewhat triangular bone, the point of the triangle directed dorso-posteriorly and overlapping the proximal end of the maxillary. At the mesial edge of the bone a short process is shown which might, in the figure, be considered as an ascending process. This is, however, probably an error in the drawing, for I have examined both Salmo trutta and Christivomer namaycush and do not find the process in either. The premaxillary bone, in both these latter fishes, is somewhat triangular, as shown by Parker in Salmo salar, but the dorso-posteriorly directed point of the triangle lies near the middle of the length of the bone and not at its mesial edge, as an ascending process should. The process, moreover, overlaps the proximal end of the maxillary, and gives articulation, on its internal surface, to that bone. It is accordingly a part of the articular process of that bone and not an ascending process. And in all of these three fishes there is an independent so-called supraethmoid.

In Elops saurus the maxillary has the relation to the premaxillary that is designated by Sagemehl as lateral. The premaxillary is without ascending process, and articulates, by its antero-mesial end, with the antero-lateral edge of a bone that Ridewood ('04.a) considers as a mesethmoid firmly united with a vomer. This mesethmoid bone of Elops is said by Ridewood to be separable without much difficulty into two components, „the upper part (supraethmoid of some authors) being a membrane bone, while the lower part, of diminutive size is a cartilage bone". In my two specimens of the fish this membrane component of the mesethmoid bone is traversed by a cross-commissural canal which is in communication, at either end, with the infraorbital latero-sensory canal. It was not possible to establish the presence of sense organs in this canal, but it is, nevertheless, quite unquestionably the homologue of the anterior or ethmoid commissure of the Crossopterygii and Ganoidei Holostei (Allis, '04), and it has never heretofore been found in any teleost. The infraorbital canal, after having traversed the anterior one of the circumorbital bones shown in Ridewood's figures,

separates into two parts, one of which turns upward and backward, in the posterior one of the two infranasal bones shown in the figures, while the other part traverses the anterior one of those two bones and then enters and traverses the membrane component of the mesethmoid. This latter bone alone, if it lodges two latero-sensory organs on either side, or this bone together with the anterior infranasal bone, if each of the bones lodges but a single organ on either side, is accordingly the homologue of the supraethmoid (median dermal ethmoid) of Amia; and in Elops, as in Amia, the one or two bones have not yet become incorporated in the premaxillary as its ascending process. The posterior infranasal bone alone (or that bone together with the anterior one, if this latter bone be not a part of the median dermal ethmoid) is the homologue of the antorbital bone of Amia, and this antorbital bone, traversed by a latero-sensory canal, has also never heretofore been described in any teleost, so far as I can find, unless it be in certain of the Siluridae (Allis, '98). This antorbital bone of Amia, and hence also the bone of Elops, is represented in Polypterus, as I have already shown ('00b), in the infranasal process of the premaxillary of that fish, and, judging from a recent work by Gaupp ('05), it must be the homologue of the septomaxillary of Amphibia and higher vertebrates. It is of dermal origin, as the septomaxillary is, and so closely resembles that bone in general position and relations to other bones that it seems quite unquestionably to represent it before it has acquired its nasal plate; that plate being a special and secondary acquisition, as Gaupp has shown.

In Macrodon, which I have examined, the premaxillary has a process similar to that in Salmo, and similar also to that shown by Sagemehl in Erythrinus, where that author considers it as an ascending process. This process in Macrodon articulates by its mesial edge with the lateral edge of the dermal component of the mesethmoid, and is widely separated from its fellow of the opposite side, exactly as Sagemehl's figures show for Erythrinus. On its internal surface there is a raised portion which gives articulation to the lateral surface of the long anterior articular end of the maxillary, and that the process is simply an articular process seems quite unquestionable, the bone then having no ascending process. And this is strictly as it should be, for the dermal supraethmoid is here said by Sagemehl to be fused with the primary mesethmoid to form the median mesethmoid bone of the fish. The supraethmoid of Macrodon would seem, however, to have been developed in relation to the median one only of two ethmoid latero-sensory ossicles on each side, and to represent a membrane component only of those ossicles, no latero-sensory organs here being found. The membrane component of the lateral one of the two ethmoid latero-sensory ossicles may then be here fused with the articular process of the premaxillary; for the outer surface of this process in Macrodon comes to the level of the adjacent dermal bones and has surface markings quite similar to those on those bones. In Elops the anterior infranasal bone, assumed to represent the lateral one of the two ethmoid latero-sensory ossicles on either side, and which is traversed in that fish by a latero-sensory canal, lies directly superficial to and in contact with the articular process of the premaxillary.

It may here be further stated, that I find, in my specimen of Macrodon, the bone called by Sagemehl ('84b, p. 95) the accessory palatine, and that, so far as can be judged from my somewhat dilapidated specimen, it is developed in the maxillary breathing valve of the fish. This, if correct, is important, for it would then be the homologue of the so-called vomer of Polypterus, a bone which I, in an earlier work ('00b), identified as the maxillary breathing valve bone of that fish. It has never heretofore been recognized in any teleost.

In Osteoglossum, according to Ridewood's ('05a) figures, the premaxillary has no ascending process, and Ridewood says that, in this fish, the „mesethmoid is a small rhombic bone of ectosteal

origin". If this bone is of dermal and not of perichondrial origin, it would seem as if it must be a supraethmoid instead of a mesethmoid, and that it must represent the missing ascending processes of the premaxillaries.

In the Cyprinidae, I can not determine whether the ascending processes of Sagemehl's descriptions are those processes or articular processes. In a specimen of Tinca that I have examined, there is but one process on the premaxillary, and it is in contact, in the median line, with its fellow of the opposite side, as an ascending process should be. It seems however highly probable that this process is simply an articular process, or perhaps that process fused with an ascending process. The ascending process would certainly be wanting if, as Sagemehl states, the mesethmoid in the Cyprinidae has, as in the Characinidae, an overlying dermal component fused with it. There is in Tinca, as Sagemehl describes for others of the Cyprinidae, a ligamentous band that connects the process of the premaxillary with the top of the ethmoid bone, and associated with the ligament there is a small median bone, the rostral of Sagemehl's descriptions; and the apparent homologue of this ligament, in Scorpaena, is associated with the articular rather than with the ascending process of the premaxillary.

The ascending process of the premaxillary in Amphibia and higher vertebrates is called by Gaupp the prenasal process of that bone. As this process in fishes quite certainly arises by the fusion of the supraethmoid with the premaxillary, the term supraethmoid process would seem a better one, if a change is to be made. And as the antorbital bones of Amia and Elops, and the septomaxillary of amphibians certainly do not belong, in their origin or development, either to the orbital or maxillary series, either infranasal or extranasal would seem to be the proper term; extranasal being the term proposed by Gaupp for the bone in the Amphibia.

The articular process of the premaxillary has never heretofore been specially described, so far as I can find, excepting by myself in Scomber and by Brooks ('84) in Gadus aeglifinus. It is, however, of very general, if not constant occurrence in the Acanthopterygii and Anacanthini. I find it in all the mail-cheeked fishes that I have examined, and also in Zeus faber, Uranoscopus scaber, Mugil capito, Sphyraena vulgaris, Gobius cruentatus, Trachurus trachurus and Lophius piscatorius, and more or less completely fused with the ascending process in Labrus, Crenilabrus and Chrysophrys aurata. It is also shown, in a more or less definite manner, by Cuvier and Valenciennes ('29) in their figures of Perca, Sciaena and Otolithus; by Bruhl ('91) in his figures of Rhombus and Labrax; by Agassiz ('33/43) in his figures of Ophidium and Vomer; by Shufeldt ('85) in his figures of Micropterus; by Supino ('01/02) in his figures of Pomatomus, Hoplostethus, Ruvettus and Macrourus; by Traquair ('65) in his figures of Hippoglossus; by Girard ('51) in his figures of Triglopsis; and in Gasterosteus, judging from Swinnerton's ('02) figures, it is probably present in much the same condition that it is in Scomber. In the Characinidae, and possibly also in the Cyprinidae, it is found, as I have just above described. In the descriptions that I have of other teleosts I can not positively recognize it. It would seem to be present in Argyropelecus (Supino '01/02), that fish certainly having an important ascending process. In Clupea harengus I find, on the internal surface of the premaxillaries, a small articular eminence that may perhaps be its homologue; but, to definitely determine this, a much more careful study of the bones and ligaments is needed than I have been able to at present give them. In Silurus glanis there is, on the dorsal surface of the premaxillary, at the lateral edge of the mesethmoid, a small process against the lateral surface of which the maxillary abuts, if not articulates. This process is shown in Jaquet's ('98) figure 39, and would seem to be an articular process. In Esox, a

similar process is found on the premaxillary, there lying immediately external to and covering the antero-mesial end of the maxillary; and this must be the articular process of the bone, if that process is not represented in bone 2 of Huxley's descriptions.

The articular process of the premaxillary of teleosts would thus seem to be as early, or even an earlier acquisition of that bone than the ascending process. This has led me to reconsider the conditions found in Amia, in which fish there is, as is well known, a large posterior process of the premaxillary, but no ascending process. This posterior process I was led, in an earlier work ('98), to consider as an olfactory sensory ossicle fused with the premaxillary, this conclusion being largely based on a description of Gymnarchus that I have since found to be erroneous (Allis, '04). My present work leads me to consider it as a greatly developed articular process of the premaxillary; for the maxillary articulates with its postero-ventral surface (Allis, '98), as it should, and its relations to the nasal sac are such as might be readily acquired by a posterior prolongation of the process of Scorpaena.

ROSTRAL.

The rostral is a median piece of cartilage, longer than it is tall, and about as tall as it is broad. Its external, or dorso-anterior surface, which is slightly concave, gives support and attachment, on either side, to the ascending process of the corresponding premaxillary. Its internal, ventro-posterior surface is considerably wider than the external one, and is grooved its full-length, in the median line, the groove fitting upon and sliding backward and forward upon the median internasal ridge. A short, stout ligament arises from the side of the rostral, and running downward and backward, is inserted on the mesial surface of what I shall describe as the ascending process of the maxillary, near its ventral edge. From the posterior half of the latero-ventral edge of the rostral, and in part, also, from its ventral surface, arises a tough fibrous or ligamentous band, which is in part inserted on the pointed mesial (proximal) end of the maxillary and in part on the shank of that bone. In that part of the band that has this latter insertion is suspended the semi-cartilaginous nodule that is interposed between the articulating surfaces of the vomer and maxillary.

In Gasterosteus, according to Swinnerton, the rostral is a chondrification, in late stages of development, of a mass of densely nucleated tissue, which, in earlier stages, lies chiefly on the underside of the ascending processes of the premaxillaries. In Salmo, Gaupp ('03) finds the rostral arising in exactly the same manner, and as he had not apparently noticed Swinnerton's description he considers the discovery of this development of this cartilage in Salmo as a support to the assumption that the premaxillary is a dermal bone developed in relation to a labial cartilage. But if the ascending process of the premaxillary is not primarily a part of that bone, as I maintain, the cartilage would seem not to have this special significance. In any event the rostral is quite certainly not a detached portion of the primordial cranium.

MAXILLARY.

The maxillary is a curved untoothed bone, with a flat, expanded hind end, and a somewhat complicated anterior end. This latter end of the bone forms its articular head, and may be said to bear two plate-like processes of bone, so placed as to give to the end of the bone a broad and somewhat V-shaped appearance. The antero-mesial (proximal) end of the shank of the bone curves rather sharply mesially and lies directly above the dorsal limb of the vomer, but it is apparently not in sliding

contact with that bone. On its ventral edge there is a pronounced angular eminence, the dorso-anterior (lateral) surface of which, and the corresponding surface of the shank of the bone above it, bears a condylar thickening which articulates, by the intermediation of a pad of semi-cartilaginous tissue, with the internal (postero-mesial) surface of the articular process of the premaxillary, the pad of tissue being suspended in tissues that are attached to the premaxillary and rostral rather than to the maxillary.

On the dorsal edge of the extreme antero-mesial (proximal) end of the maxillary there is a small bluntly pointed process which projects dorso-mesially and touches, or almost touches, the ventral surface of the rostral, being bound to that cartilage by tough fibrous tissue. Beginning at the base of this little process, a flange-like process rises from the dorsal edge of the maxillary, extends distally a short distance along the shank of that bone, and then turns transversely, almost at right angles, across its dorsal surface. The process thus has longitudinal and transverse portions, the latter of which is much the more important and forms a tall flange-like portion of the entire process which lies perpendicularly to the maxillary and approximately in a vertical longitudinal plane of the body. This right-angled and flange-like process may be called the ascending process of the maxillary. Into the angle between its two portions the postero-lateral edge of the articular process of the premaxillary fits, the ascending process of the maxillary thus embracing and giving articulation, in the angle between its two parts, to the edge of the articular process of the premaxillary. From the mesial surface of the transverse portion of the process, a strong ligament, already referred to, runs upward and backward and is inserted on the lateral surface of the rostral, near its ventral edge.

The transverse limb of the ascending process of the maxillary is longer than the shank of the maxillary is wide, and hence projects anteriorly beyond the lateral edge of that shank. The ventral edge of this projecting portion of the ascending process is fused with the anterior end of another plate-like process of the maxillary, this latter process arising in a longitudinal line from the dorso-anterior (lateral) surface of the shank of the bone, beginning immediately distal to the ascending process. This longitudinal process, which may be called the ligamentary process of the bone, projects downward and forward, eaves-like, along the anterior (lateral) surface of the premaxillary. It gives insertion, on the antero-mesial (proximal) corner of its external, dorso-anterior surface, to the ethmo-maxillary and naso-maxillary ligaments, which ligaments from there run postero-dorso-mesially to their points of origin on the mesethmoid process and the nasal bone respectively; the ligaments, in their course, lying upon and crossing latero-mesially the anterior edge of the ascending process of the maxillary. From the antero-mesial (proximal) edge of the process a wide band of fibrous tissue arises, and, running mesially, crosses the external surfaces of the ascending processes of the two premaxillaries, near their bases, and has its insertion on the antero-mesial edge of the ligamentary process of the maxillary of the opposite side. The cut ends, only, of this band are shown in the figures. This intermaxillary band of tissue, together with the short ligament, on either side, and already described, that extends from the base of the ascending process of the premaxillary to the mesial (proximal) end of the ligamentary process of the maxillary, hold the two maxillaries against the edges of the articular processes of the premaxillaries, the two ligaments being directly opposed to a ligament that arises from the extreme postero-lateral (distal) corner of the ligamentary process. This latter ligament runs postero-ventrally across the dorsal surface of the shank of the maxillary and then onward along the internal surface of that bone, lying in the thin membrane that extends from the inner surface of the maxillary, near its dorsal edge, to the ventro-lateral edge of the palato-quadrate apparatus, and that forms part

of the lateral wall of the buccal cavity. The ligament here lies along the anterior edge of the superficial division, A_1, of the adductor mandibulae muscle, and separates into a number of ligamentous strings. These strings soon reunite into a broad ligamentous band which passes over the external surface of a tough pad of fibrous tissue that covers the coronoid process of the mandible, and there separates into two parts, both of which continue onward and have their insertions on the external surface of the articular, along a ridge that forms the ventral margin of the articular facet for the quadrate. As the ligament passes over the coronoid pad of fibrous tissue there is apparently an interchange of fibers with that pad. This ligament, in Scomber, gives insertion to a part of the deeper division, A_3, of the adductor mandibulae muscle, and is the tendon A_3mx of my descriptions of that fish.

Between the ventro-anterior (lateral) edge of the ligamentary process of the maxillary and the proximal portion of the shank of that bone, there is a wide V-shaped groove. This groove fits upon the dorsal edge of the premaxillary, immediately distal to the base of the articular process of the bone, and also embraces the basal portion of that articular process itself. The articular process of the premaxillary articulates, however, with the shank and ascending process of the maxillary, in the manner just above set forth, and not with its ligamentary process, although this latter process may have a secondary participation in this articulation.

On the dorsal surface of the ligamentary process, in the angle between it and the lateral (distal) surface of the ascending process of the bone, there is a little pit-like depression which gives support and articulation to the anterior end of the maxillary process of the palatine, that process being firmly but moveably bound to the maxillary. Immediately postero-lateral (distal) to this articular surface, the ligamentary process gives support, on its dorsal surface, and is firmly bound by ligamentous tissue to, the anterior, process-like end of the lachrymal.

On the dorso-posterior (mesial) surface of the shank of the maxillary, opposite the postero-lateral (distal) end of its ligamentary process, there is a depression which gives insertion to a short tendon of the dorsal portion of the superficial division, A_1, of the adductor mandibulae muscle; this insertion of the tendon of this muscle thus differing from that in Scomber, where it is inserted on the inner surface of the lachrymal.

The ascending process of the maxillary is directed dorso-posteriorly, and its summit is thickened to form an even, smooth and slightly curved edge, which is covered, in the recent state, with glistening connective, or semi-cartilaginous tissue. The postero-ventral portion of this curved edge has a sliding articulation, through the intermediation of a pad of tough fibrous or semi-cartilaginous tissue, with the dorsal surface of the dorsal limb of the vomer. The pad of semi-cartilaginous tissue is suspended in that fibrous band that extends from the ventral surface of the rostral to the proximal end of the shank of the maxillary, and that has already been described. The remaining and larger portion of the summital edge of the process, although having the appearance of an articular surface, does not articulate with any structure. It, however, in its motion, rubs against the internal surface of the ethmo-maxillary ligament, against the anterior edge or internal surface of the rostro-palatine ligament, and rubs and pushes against the anterior surface of the nasal sac.

An ascending process of the maxillary is doubtless present in all the Acanthopterygii and Anacanthini; but it is certainly not always developed to the extent, and in the manner that it is in Scorpaena. In Scomber, for instance, the single process of Scorpaena is represented by two separate processes. One of these processes is longitudinal in position, articulates by its dorsal edge with the

dorsal limb of the vomer, and was described by me as the dorsal articular head of the bone. The other is represented in the little process which not only gives insertion to the ethmo-maxillary ligament, but also articulates, by its antero-mesial surface, with the articular process of the premaxillary. In Amia, the process is not evident, nor is it in Salmo (Parker, '73), Esox, Citharinus (Sagemehl, '84b), Hydrocyon (Sagemehl, '84b), Elops (Ridewood, '04a), Megalops (Ridewood, '04a), Albula (Ridewood, '04a), Mormyrops (Ridewood, '04b), Notopterus (Ridewood, '04b), or Gymnarchus (Erdl, '47). But in several of these fishes there is a bend in the maxillary, near its proximal end, and at this bend there is an eminence on the bone which may quite probably represent the well-developed process of the Acanthopterygii and Anacanthini. This can only be determined when these fishes shall have been much more carefully described than they have been up to the present time.

In Gonorhynchus Greyi, according to Ridewood ('05 b), „There is no articulation between the ethmoid region of the cranium and the maxilla, nor between the ethmoid and the premaxilla". The premaxillary, as shown in Ridewood's figures, is here without either ascending or articular processes, the maxillary is without ascending process, the vomer is apparently without ascending processes, and the preëthmoid (septomaxillary), if present, is apparently fused with the mesethmoid. This all seems to need further examination.

NASAL SAC.

The nasal sac of Scorpaena is large, and has two large diverticula. The posterior surface of the sac lies against the anterior surface of the ectethmoid, occupying the space between the preocular spinous ridge and the lateral edge of the arm of the bone. The posterior nasal aperture lies at the tapering dorsal end of this portion of the sac, immediately lateral to the preocular spinous ridge; the anterior aperture lying slightly anterior to it, approximately between the summit of the mesethmoid process and the dorso-lateral corner of the arm of the ectethmoid. The anterior opening of the olfactory canal through the antorbital process lies in this same region, approximately ventral to the anterior edge of the posterior nasal aperture. As the olfactory nerve issues from its canal, it turns dorsally, at the same time spreading in a postero-anterior direction, and, pushing the floor of the sac upward, forms a stout vertical partition which rises from the floor and anterior wall of the sac and reaches upward nearly to its roof. It bears, on its summit, a rosette of sensory tissue, this rosette lying directly beneath the anterior nasal aperture. The floor of the nasal sac extends forward, on either side of this sensory partition, to the level of the summital edge of the ascending process of the maxillary, which edge abuts against the anterior end of the partition. The floor of the nasal sac is thus here U-shaped. The lateral leg of the U lies directly above the open oval space, already described, that lies between the lateral edge of this part of the skull and the dorso-mesial edges of the lachrymal and palatine, this space being closed, ventrally, by the lining membrane of the mouth cavity.

From each leg of the U-shaped nasal sac, an important diverticulum arises, these diverticula doubtless being the „nasal sacs" or „reservoirs" that Kyle ('00) says are found in the Scorpaenidae, but which I cannot find that he describes. The diverticulum that arises from the lateral leg of the U is the larger one of the two. It passes beyond the lateral edge of the skull, and there lies in the space enclosed between the lachrymal above, and the palatine below. It has a short posterior prolongation and a longer anterior one. The posterior prolongation lies along the ventro-lateral edge of the arm of the ectethmoid, between the two articular surfaces on that edge. The anterior end of

the anterior prolongation passes along the lateral surface of the maxillary process of the palatine, and then turns mesially beneath that process, between it and the lining membrane of the roof of the mouth cavity, and abuts and terminates against the lateral (distal) surface of the ascending process of the maxillary.

From the mesial or dorso-mesial surface of the mesial leg of the U-shaped sac the mesial diverticulum has its origin, this diverticulum being formed of a noticeably delicate and very flexible membrane. It lies against the lateral surface of the rostral, has a short anterior prolongation between the rostral and the mesial surface of the ascending process of the maxillary, and a longer posterior prolongation which extends around the hind end of the rostral, and there meets, but in the adult, so far as could be determined by dissection, does not communicate with the corresponding diverticulum of the opposite side. In 45 mm specimens the diverticula are apparently here in large and free communication with each other. From the disposition of the diverticula, it is evident that when the mouth is protruded and retruded the capacity of the nasal sac is first considerably enlarged and then diminished, the circulation of the water in it thus being facilitated, as Kyle has stated.

NASAL.

The nasal is a small bone, which, by a downwardly projecting portion of its hind end, fits against and is firmly attached to, the lateral surface of the mesethmoid process. It encloses the nasal portion of the supraorbital latero-sensory canal, and bears, on its hind end, the nasal spine. From its anterior end the naso-maxillary ligament arises, and running forward and downward is inserted on the ligamentary process of the maxillary. On its inner surface, near its hind end, and also on the adjacent ligamentary surface of the mesethmoid process, the ethmo-maxillary ligament and the small rostro-nasal branch of the large palato-rostral ligament both have their attachments.

FRONTAL.

The frontal touches, in the mid-dorsal line, throughout nearly its entire length, its fellow of the opposite side. At its anterior end its lateral edge rests upon the dorsal surface of the ectethmoid, its mesial edge resting upon the dorsal surface of the pointed posterior portion of the mesethmoid. In the anterior half of the orbital region, its mesial edge rests upon the dorsal edge of the interorbital septum, that septum being a thin wall, cartilaginous in its anterior but membranous in its posterior portion. In the posterior half of the orbital region a thin flange-like process has its origin from the ventral surface of the frontal, the line of origin of the process running, at first, backward and but slightly laterally, and then turning laterally, in a rounded angle, toward the postorbital corner of the lateral edge of the bone. From this line of origin the flange projects downward, backward and mesially, beginning at nothing anteriorly, increasing gradually in depth until it reaches the rounded angle of its line of origin, and then diminishing again almost to nothing shortly before it reaches the postorbital corner of the bone. The ventral edge of the anterior half of the flange, that is, up to its deepest point, gives attachment to the dorsal edge of the membranous posterior half of the interorbital septum; the flanges of opposite sides, which touch in the middle line throughout a part of this distance, enclosing an anterior portion of the cranial cavity. Posterior to its deepest point, the flange, turning laterally, overlaps externally and lies closely against the external surface of the dorsal half of the alisphenoid, the base of the flange resting against the external surface of the

line of cartilage that caps the dorsal edge of that bone, and the body of the frontal, immediately postero-mesial to the flange, resting upon the dorsal surface of this same line of cartilage. Postero-internal to this large flange and slightly postero-lateral to the antero-mesial end of the line of alisphenoid cartilage, a short narrow and pointed process projects downward from the ventral surface of the frontal, lies against the internal, postero-mesial surface of the cartilage, and may even extend ventral to the cartilage, there lying against the corresponding surface of the alisphenoid. This little process of the frontal, and the large flange-like process of the same bone, thus clasp and hold between them the dorsal end of the alisphenoid, in a manner similar to that described by me for these same bones in Scomber. From the hind edge of the little process a delicate ridge runs postero-mesially toward the postero-mesial corner of the frontal. It corresponds to the flange that, in Scomber, forms the lateral boundary of the post-epiphysial cartilage, that cartilage being reduced, in Scorpaena, to a narrow band along the anterior edge of the supraoccipital. Postero-lateral to the alisphenoid, the greatly diminished flange of the frontal overlaps slightly, or abuts against, the dorsal edge of the sphenotic.

The lateral edge of the frontal, at and posterior to its postorbital corner, rests upon the dorsal surface of the sphenotic, the mesial corner of its hind edge resting upon the dorsal surface of the supraoccipital, and the hind edge of the bone articulating by suture with the anterior edges of the pterotic and parieto-extrascapular. Adjacent to the sphenotic and supraoccipital bones the frontals each rest upon small cartilaginous remnants of the chondrocranium; and between these cartilages and the related bones, they form part of the roof of the cranial cavity, covering a large median opening in the roof of the chondrocranium formed by the fusion of the anterior ends of the lateral fontanelles. This median opening is open anteriorly, there being no cartilaginous epiphysial ridge to form its anterior boundary; Sagemehl's statement that this ridge is found in all teleosts thus not being correct.

The frontal is traversed by the supraorbital latero-sensory canal and lodges five organs of that line, two of these organs, the 4th. and 5th. of the line, lying relatively close together, without an intervening primary tube, as will be fully explained when describing the canals. The position of that part of the canal that lies between the orbits is marked by a strong ridge, already several times referred to as the frontal or interorbital ridge. A similar ridge marks approximately the position of the fourth tube of the line; that tube running mesially and slightly backward to meet, in the middle line, its fellow of the opposite side. The hind edge of this ridge forms the anterior boundary of the groove on the vertex.

That part of the cranial cavity that is enclosed between the anterior halves of the ventral flange-like processes of the frontals corresponds to the fore-brain recess of my descriptions of Scomber, but, in Scorpaena, the cranial cavity is so large, relatively to the brain, that the fore-brain lies wholly posterior to the recess, reaching, approximately, only to the anterior edge of the basisphenoid. The olfactory nerves there pierce the membranes that close the orbital opening of the brain case, and, enclosed in a membranous tube, traverse the orbit. The fore-brain recess of the adult Scorpaena thus lodges no portion of the brain, being simply filled with fatty tissue.

POSTFRONTAL.

The postfrontal is a small flat bone which lies directly upon, and is quite firmly bound to, the posterior portion of that part of the dorsal surface of the sphenotic that is not covered by the frontal and pterotic. Along its anterior and lateral edges, narrow strips of the sphenotic appear, and form

part of the dorsal surface of the skull. The postfrontal forms part of the roof of the dilatator fossa, bears two or three short blunt spines, and is traversed by the main infraorbital latero-sensory canal, lodging one organ of that canal, innervated by the ramus oticus lateralis.

In Scorpaena porcus, the postfrontal is a short, small, tubular bone, and bears but one, or at most two spines.

PARIETO-EXTRASCAPULAR.

The parieto-extrascapular is formed by the fusion of the parietal with the mesial ossicle of the extrascapular latero-sensory series. This fusion, in certain other fishes, of these two usually separate elements was fully discussed by me in a recent work ('04). As further confirmation of the fusion, the conditions in Chanos can be cited, where, according to Ridewood ('04a, p. 58), „the parietals are widely separated in the young but by subsequently fusing with the scales of the commissural section of the sensory canal system, they come to meet above the supraoccipital bone".

In Scorpaena, the parieto-extrascapular is a relatively large and very irregular bone, with a much ridged dorsal surface. One of these ridges is the parietal spinous ridge, which has already been described. Another and lower ridge lies immediately lateral to the parietal ridge, is formed, anteriorly, by the lateral bounding ridge of the groove on the vertex, and, posteriorly, by the nuchal spinous ridge; the ridge being interrupted between these two portions. Immediately lateral to this ridge, there is a curved ridge, tall in its middle portion but low at either end, the hollow of the curve presented laterally. The posterior portion of this ridge marks the course of a part of the supratemporal latero-sensory canal. A mesially projecting corner of the bone lies on the posterior portion of the dorsal surface of the supraoccipital, articulates by suture, usually serrate, with its fellow of the opposite side, and forms the summit of the ridge that bounds posteriorly the groove on the vertex. A large reëntrant angle at the postero-lateral corner of the bone receives the antero-mesial corner of the lateral extrascapular, the edges of this part of the parieto-extrascapular overhanging slightly the temporal fossa and forming part of its roof.

The posterior half of the parieto-extrascapular is a stout, broad process-like portion which projects postero-laterally and lies slightly dorsal to the dorsal surface of the suprascapular process of the epiotic; the narrow space between itself and that process of the epiotic receiving the epiotic arm of the suprascapular. From the internal surface of this part of the bone, near its hind edge, a delicate flange projects ventro-posteriorly. The antero-ventral surface of this flange lies upon that part of the dorsal surface of the epiotic that lies immediately anterior to the base of the suprascapular process of that bone. The postero-dorsal surface of the flange forms part of the floor of the supratemporal pocket and thus forms part of the apparent posterior surface of the adult skull, but it lies on a part of the dorsal surface of the primary skull, and not on its posterior surface, as already explained.

The anterior half of the parieto-extrascapular rests in part upon the dorsal surface of the pterotic and supraoccipital, in part upon remnants of the chondrocranium adjacent to those bones, while, in part, it bridges the lateral fontanelle of the skull, there forming part of the roof of the cranial cavity. The anterior edge of the bone articulates by suture with the hind edge of the frontal, the mesial edges of the parieto-extrascapulars not here meeting in the middle line, and a median portion of the supraoccipital being exposed between them. The bone is traversed by the supratemporal latero-sensory canal, the canal usually lodging a single sensory organ, but in one specimen this organ had apparently separated into two parts, lying close together. In 45 mm specimens there is but a

single organ here, this showing that but a single extrascapular latero-sensory ossicle has here fused with the parietal.

The parietal spine on the dorsal surface of the parieto-extrascapular belongs to the anterior, parietal part of the bone, the nuchal spine belonging to the posterior, extrascapular part.

LATERAL EXTRASCAPULAR.

The lateral extrascapular, the only independent extrascapular element there is in the skull of Scorpaena, is a small plate-like bone that forms the larger part of the roof of the temporal fossa. Its lateral edge rests upon the dorsal edge of the posterior process of the pterotic, and its posterior edge upon the dorsal surface of the suprascapular. Its anterior and mesial edges are almost entirely enclosed in the reëntrant angle in the postero-lateral corner of the parieto-extrascapular, from which bone the extrascapular is separated by a narrow space bridged by fibrous tissue, this tissue holding the extrascapular in place, forming part of the roof of the temporal fossa, and transmitting the supratemporal canal. The bone encloses a section of the main infraorbital latero-sensory canal, and also the lateral portion of the supratemporal canal, lodging one sense organ of each of those canals. The bone bears, on its hind edge, the anterior one of the two spines of the intermediate line.

SUPRASCAPULAR.

The suprascapular has a mesial, or epiotic, and an inferior, or opisthotic process, the epiotic process forming the larger part of the bone and running insensibly into the body of the bone. The body of the bone, which forms the lateral edge of the entire bone, encloses a short section of the main infraorbital canal and lodges one organ of that canal. The epiotic process projects upward forward and mesially, and rests upon the dorsal surface of the suprascapular process of the epiotic, fitting closely into a narrow space between that bone, below, and the ventral surface of the projecting posterior portion of the parieto-extrascapular above. The process of the suprascapular is firmly bound to each of these two latter bones, its position relative to the posterior portion of the parieto-extrascapular being that that it normally has to an extrascapular bone. The opisthotic process of the bone projects ventro-antero-mesially and rests upon and is bound by tissue to a thickened portion of the hind edge of the opisthotic. The process lies along, or internal to, the hind edge of the posterior process of the pterotic, and forms the lateral wall of the posterior opening of the temporal fossa. On the internal surface of the postero-lateral corner of the bone, close to its hind end, there is a small articular eminence, and immediately antero-mesial to this eminence, an articular facet; the two surfaces articulating with corresponding surfaces on the dorso-anterior corner of the supraclavicular. The bone bears, on its hind edge, two spines, one belonging to the lateral row of spines and the other to the intermediate row. It is traversed by the main infraorbital latero-sensory canal and lodges a single organ of that line.

SUPRACLAVICULAR.

The supraclavicular is a triangular bone. It lies along the outer surface of the clavicle, and articulates, by two articular surfaces on its dorso-anterior corner, with the ventral surface of the suprascapular. One of these two articular surfaces is an articular head that rises prominently from the anterior end of the dorsal edge of the bone, the other being an articular facet that lies immediately latero-posterior to the articular head. The dorsal edge of the bone, posterior to these articular surfaces,

is traversed by the main infraorbital canal, and lodges one organ of that canal. The hind corner of the bone may be either sharp or rounded, and as it forms a slight eminence in the dermis may be considered as the last spine of the lateral row. The occipito-supraclavicular ligament is inserted on the internal surface of the supraclavicular, in the usual manner.

LATERAL SURFACE OF THE BRAIN CASE.

The lateral surface of the brain case of Scorpaena is inclined at an angle of 45°, approximately, to the horizontal plane. Its ventral half is crossed transversely, from above downward and backward, by the elongated, fusiform and prominent swelling of the bulla acustica. Anterior to this swelling, there is, on the ventral half of the lateral surface of the brain case, a depressed region which lies on the proötic and parasphenoid. The posterior and larger part of this depressed surface is filled by and gives attachment to a large tough pad of connective and muscular tissue, which is continuous, across the middle line, with a similar pad on the other side, the two together representing the anterior transversus dorsalis muscle. The lateral border of the pad of either side gives attachment to a short muscle which has its insertion on the epibranchial of the second arch, and is the obliquus dorsalis of that arch; the two short muscles, one on either side, together with the intervening pad, forming a single mass, as in Scomber. The posterior transversus dorsalis is a thin band of muscle extending from the third and fourth epibranchials of one side transversely across to the corresponding bones of the other side.

Anterior to the anterior transversus dorsalis, the infrapharyngobranchial of the first arch is attached to the side wall of the skull; and, anterior to that element, the posterior portion of the adductor arcus palatini has its origin. The surface of origin of this latter muscle begins immediately ventral to the trigeminus opening of the trigemino-facialis chamber, there lying partly on the proötic and partly on the ascending process of the parasphenoid. From there it extends downward and forward along the anterior portion of the latter process, and then turns directly forward, occupying a depressed region along the lateral edge of the body of the parasphenoid and extending forward across the orbit to the antorbital process of the skull. From this long surface of origin the broad and relatively thin muscle extends latero-ventrally and has its insertion mainly on the palato-quadrate arch, as will be later more fully described, its posterior portion, however, having its insertion on the inner surface of the thin flange of bone that forms the anterior edge of the hyomandibular. The muscle thus acts in part as an adductor hyomandibularis, but it is widely and wholly separate, both at its origin and insertion, from the latter muscle, properly so-called.

Immediately dorsal to the anterior end of the bulla acustica is the opening usually called the facial foramen, but this so-called foramen is, as in Scomber, the facialis opening of the trigemino-facialis chamber. Posterior to this opening, and extending across the lateral surface of the skull to its hind edge, there is a large, shallow, and, in certain specimens, distinctly pyramidal depression which lies on the proötic, opisthotic and exoccipital bones. The depression is subtriangular in outline, the base of the triangle being formed by the dorsal edge of the anterior portion of the bulla, the posterior edge by a part of the postero-lateral edge of the skull, and the antero-dorsal edge by a low ridge that runs downward and forward across the lateral surface of the brain case, approximately in the line prolonged of the opisthotic process of the suprascapular. The center of the depression, somewhat pointed in certain specimens, lies within the arch of the external semicircular canal, ventral to that canal, and in this the depression corresponds to the subtemporal fossa of Sagemehl's

descriptions of the Cyprinidae, but, as described immediately below, it does not correspond with that fossa in the muscles to which it gives origin. The anterior corner of the depression is connected by a shallow groove with the facialis opening of the trigemino-facialis chamber, this groove lodging the nervus sympatheticus and the ramus anterior of the nervus glossopharyngeus. In the postero-ventral corner of the depression is the vagus foramen, and slightly anterior to that foramen, near the ventral edge of the depression, is the glossopharyngeus foramen, both of these foramina perforating the exoccipital.

Dorsal to the subtriangular depression above described, the posterior half or three-fifths of the dorsal half of the lateral surface of the skull is markedly flat. Anterior to this flat portion, there is a large and deep fossa, on the proötic and pterotic bones, the fossa lying immediately antero-ventral to the elongated facet for the posterior articular head of the hyomandibular, and antero-dorsal to the arch of the external semicircular canal. The anterior border of this fossa is formed by a strong flat process of the proötic, this process lying directly dorsal to the facialis opening of the trigemino-facialis chamber and immediately posterior to the rounded oval and relatively deep facet for the anterior articular head of the hyomandibular. Partly in the dorsal portion of this fossa and partly on the process that forms its anterior border, the two internal levators of the branchial arches and the external levators of the first three branchial arches have their origins. The external levator of the first arch was little more than a band of membrane on one side of the head of the single specimen examined in this respect; and on this same side of the head of this one specimen the external levator of the third arch was wholly wanting, while on the other side it was a slender muscle much smaller than any of the others. The several muscles all arise together, as a group, the internal levators arising in a line that lies immediately postero-ventral to the line of origin of the external muscles. The levator internus anterior lies internal to the other muscles, and is a stout one which bellies considerably immediately beyond its origin, the belly of the muscle completely filling that large part of the fossa that lies ventral to the surface of origin of the muscles. This large part of the fossa thus seems to have been formed by the compressive action of this muscle, and not in relation to the points of origin of the several muscles of the group.

On the flat surface of the skull posterior to this fossa, and also partly in the subtriangular depression, the adductor hyomandibularis and adductor operculi have a large surface of origin. These two muscles are not contiguous at their origins, the surface of origin of the adductor operculi lying slightly posterior to and being slightly larger than that of the adductor hyomandibularis. Dorsal to these two muscles, in a long and narrow line along the dorso-lateral edge of the skull, the levator operculi has its origin. Immediately posterior to the surface of origin of the adductor operculi, in a narrow line near the hind edge of the skull, the external levator of the fourth arch has its origin, this fourth levator, in the one specimen examined, having its insertion on the fourth arch and not on the inferior pharyngeal bone. Posterior to this fourth levator, and in contact with it, a flat muscle has its origin, and running posteriorly has its insertion on the dorsal portion of the clavicle, thus corresponding to the fifth levator of my descriptions of Scomber. This fifth levator would seem to be the homologue of the muscle that Herrick considers ('99, p. 117), in Menidia, as the trapezius muscle. It would seem as if it must also be the homologue of the muscle described by Sagemehl ('84 b, p. 49), in the Characinidae, as the Attractor of the shoulder girdle, that muscle being said to arise from the skull and to have its insertion on the supraclavicular. Vetter concluded that a trapezius muscle is wanting in Teleosts, as Herrick himself states.

There are thus, on the lateral surface of the skull of Scorpaena, two separate depressions in each of which certain of the levator and adductor muscles of the visceral arches have their origins, and the anterior one of the two seems certainly to have been developed in some relation to the muscles that have their origins in it. With the posterior depression, this causal relation is much less evident, and it would seem as if the anterior depression of Scorpaena must be superimposed upon the posterior one to form the subtemporal fossa of Sagemehl's and Ridewood's descriptions of the Cyprinidae. Sagemehl says that this fossa in these latter fishes is formed as the result of the origins of certain of the levator muscles on this particular part of the skull, and he says that, in the Barbidae, the adductor operculi arises in the anterior part of the fossa, and the external levator of the fourth arch in its posterior portion. Of the other Cyprinidae he simply says that the levators of the branchial arches arise from the side walls of the skull below the adductor hyomandibularis and adductor operculi. Ridewood says ('04 a, p. 62) that, in certain of these same fishes, the fossa serves „for the lodgment of the great muscles, which by pulling up the inferior pharyngeal bones (fifth ceratobranchials) bring the teeth upon those bones forcibly against the callous pad that is carried on the under surface of the basioccipital bone"; and Vetter says ('78, p. 505) that, in Cyprinus and Barbus, the levatores arc. branch. externi have their origins in part in this fossa, that they are in part inserted on the hind surface of the outer corner of the large inferior pharyngeal bone, and that they press that bone against the bony plate on the under surface of the basioccipital. It seems, accordingly, to be to certain of the external levators alone that the fossa-forming quality is attributed, and when they happen to have their points of origin on the side wall of the skull in the region of the subtriangular depression of Scorpaena, they apparently may cause a deepening of that depression and so give rise to a true subtemporal fossa. The subtriangular depression of Scorpaena would accordingly seem to be a rudimentary fossa, and may be called the subtemporal depression. In the Barbidae and Homaloptera this depression is deepened to such an extent that the epiotic is seen at the bottom of it (Sagemehl, '91, p. 554); while in Elops, according to Ridewood, the supraoccipital also is there exposed.

Immediately ventral to the surface of origin of the adductor hyomandibularis, on the dorsal portion of the bulla acustica, a large bundle of the muscles of the trunk has its origin.

THE ORBIT.

The orbit is large. The interorbital septum is cartilaginous in its anterior and larger portion, but membranous in its posterior portion. The ventral half of this membranous portion is attached posteriorly to the anterior edge of the pedicle of the basisphenoid. Above the dorsal end of that pedicle, the membrane spreads laterally, on either side, and is attached to the anterior edge of the body of the basisphenoid, and, above that bone, to the ventral edge of the alisphenoid and then to the ventral edge of the ventral process of the frontal; the membrane thus closing the orbital opening of the brain case. This membrane is pierced, on either side, and immediately above the basisphenoid, by the optic nerve. Slightly above the optic nerves, the two oflactory nerves enter a small median pocket in the membrane, from which a membranous tube leads forward on either side of the interorbital septum. Having traversed this tube, the olfactory nerve of either side continues forward, in the orbit, lying along the lateral surface of the cartilaginous portion of the interorbital septum and so reaches and then traverses the olfactory canal through the ectethmoid. Lateral to the olfactorius, and along, or enclosed in, the ventral edge of the alisphenoid, the trochlearis enters the orbit.

ORBITOSPHENOID.

There is no orbitosphenoid.

ALISPHENOID.

The alisphenoid is sub-oval in outline. Its dorso-anterior third or half is overlapped externally by the posterior portion of the ventral process of the frontal. Its dorsal edge is capped with cartilage, and this cartilage rests against the ventral surface of the frontal immediately internal to the ventral process of that bone. The anterior edge of the bone is presented mesially and but slightly forward, and suturates with the ventral flange-like process of the frontal. Its posterior edge is presented laterally and but slightly backward and is bounded, in its dorsal portion, by the sphenotic and the body of the proötic, but is separated from both of those bones by a line of cartilage. The ventro-posterior corner of the bone suturates, without intervening cartilage, with the dorso-anterior edge of the prepituitary portion of the mesial process of the proötic and with the antero-lateral corner of the body of the basisphenoid. Its ventral edge forms part of the boundary of the orbital opening of the brain case and gives attachment to the membranes that, in the recent state, close that opening.

On the internal surface of the alisphenoid, near its anterior edge, a ridge runs downward a short distance from the dorsal edge of the bone. This ridge is continuous with a similar ridge on the corresponding surface of the cartilage that caps the bone, and is also continuous with, or is slightly overlapped by, the little ridge and process, already described, on the ventral surface of the frontal. The entire ridge thus formed, forms the posterior boundary of what I have referred to as the fore-brain recess of the cranial cavity, that recess thus lying mainly anterior to the alisphenoid, and the alisphenoid bounding the mid-brain region.

A small foramen is always found perforating the alisphenoid, and the ventral edge of the bone, where it bounds the orbital opening of the brain case, is always notched to form an imperfectly closed and larger foramen. The small foramen transmits a small nerve accompanied by two small arteries; the nerve being a branch of the ophthalmicus lateralis destined to innervate organ 6 of the supraorbital canal, but accompanied by other fibers, probably general cutaneous, and the arteries being, one a branch of the external carotid and the other a branch of a blood vessel to be later described as the vessel x and that would seem to represent, in part at least, the hyo-opercularis artery of my descriptions of Amia. The notch in the ventral edge of the bone transmits the nervus trochlearis. Dorso-anterior to this notch, and close to it, a smaller notch transmits a branch of the orbito-nasal vein. In Amia, this small vein perforates the alisphenoid, and in my descriptions of that fish I called it the anterior cerebral vein. In Scomber a corresponding foramen was found in the alisphenoid, and I assumed that it transmitted a corresponding vein, as it doubtless does. In Ophiodon, Allen ('05) does not describe this vein, but it would seem as if it must there be found for I find it in Cottus, Trigla, Peristedion and Dactylopterus as well as in Scorpaena, but perforating the alisphenoid in all those fishes instead of passing across its anterior edge. It would seem, even, to have a certain morphological importance, though what it may be I can not yet determine. It, or the foramen that transmits the branch of the external carotid, or these two foramina together, may perhaps represent the foramen spinosum of human anatomy.

On the outer surface of the posterior portion of the alisphenoid, and extending to its ventral edge, there are two more or less developed ridges. The postero-lateral one of these two ridges is often wholly wanting, the antero-mesial one being present, more or less developed, in all my specimens. The

ventral end of each of these ridges projects, as a small process, toward the dorsal end of the ascending process of the parasphenoid, and is connected by fibrous tissue with the dorsal end of that process, this tissue bridging, to reach the parasphenoid, a narrow intervening portion of the orbital surface of the proötic. The tissue related to the antero-mesial ridge is always more strongly developed than that related to the postero-lateral one, being almost ligamentous in character. In one specimen it had even become entirely ossified by invading growths from the alisphenoid and parasphenoid, a complete bony foramen thus being formed which is the homologue of the internal jugular foramen of Allen's ('05, p. 81) descriptions of Ophiodon. When the ligamentous tissue does not ossify, and that is the usual condition in the specimens that I have examined, the foramen becomes an internal jugular notch. The bottom of this notch, or the mesial border of the foramen when there is a foramen, is usually, but not always marked by a slight ridge on the proötic; and this ridge, where there is simply a notch, forms the dorso-lateral corner of the orbital opening of the myodome, and separates that opening from a groove on the posterior wall of the orbit. This groove lies on the orbital surface of the proötic, leads dorso-postero-laterally into the trigeminus opening of the trigemino-facialis chamber, and lodges not only the internal jugular vein, but also the truncus ciliaris profundi. Because of the name given to the foramen (or notch) that forms its antero-mesial boundary, the groove can be called the internal jugular groove. Coming along this groove, the truncus ciliaris profundi passes through the internal jugular notch, mesial to the spanning ligament, and then turns forward, in the orbit; the nerve thus entering the orbit mesial to, and hence morphologically anterior to, the spanning ligament. The oculomotorius traverses a foramen in the proötic the external aperture of which lies immediately antero-mesial to the internal jugular notch, and then runs forward in the orbit, thus also lying mesial and hence morphologically anterior to the band of ligamentous tissue. The trochlearis has similar relations to the band of tissue, while the trigeminus and lateralis nerves issue, and always lie, lateral, and hence morphologically posterior to it. The band of ligamentous tissue and the associated process-like ridge of the alisphenoid, thus together correspond exactly, in their relations to these cranial nerves, to the pedicle of the alisphenoid of Amia; and if, in Scorpaena, the process of the alisphenoid were alone to be prolonged, by ossification of the ligament, its ventral end would rest upon the ascending process of the parasphenoid, and, interno-posterior to that process, upon a portion of the lateral bounding wall of the orbital opening of the myodome, exactly as it does in Amia. The process and band, together, are thus quite certainly the homologue of the pedicle of the alisphenoid of Amia.

That small part of the alisphenoid of Scorpaena that lies ventral to its slightly developed pedicle must then correspond to that flange of the alisphenoid of Amia (Allis, '97a, fig. II) that lies internal to the well-developed pedicle of the bone of that fish. In Amia this flange of the alisphenoid gives attachment to the dorsal edge of the tough membrane that, in that fish, forms the lateral wall of the cranial cavity and the mesial (morphologically anterior) wall of the tall orbital opening of the myodome. Ventrally this membrane is closely attached (Allis, '97a, p.494) to the dorsal surface of the transverse cartilaginous prepituitary bolster of the fish; and in this part of the membrane, or perhaps partly also in tissues that remain after the resorption of the cartilaginous bolster, the body and pedicle of the T-shaped basisphenoid of teleosts are developed. In both Scomber and Scorpaena the ventral edge of the alisphenoid suturates with the lateral edge of the body of the basisphenoid; this showing that a portion of the membrane that forms the antero-mesial wall of the orbital opening of the myodome of Amia is alisphenoid membrane, and potentially a part of the alisphenoid bone.

The alisphenoid of Amia and teleosts is thus, in principle, an inverted Y-shaped bone, the anterior arm of the inverted Y resting on the lateral edge of the actual or potential basisphenoid, and the posterior leg resting on the lateral and morphologically posterior wall of the orbital opening of the myodome, the ascending process of the parasphenoid there coming into supporting relations with it. The bone thus straddles the orbital opening of the myodome, and through the passage between its legs, in Amia, the oculomotorius, trochlearis, and profundus nerves enter the orbit; the passage not, however, representing the fused foramina of those nerves (Allis, '97b), their true foramina being where they respectively pierce the membrane which, in Amia, forms the entire lateral bounding wall of this part of the cranial cavity. All three of the nerves, in Amia, certainly lie anterior to the parasphenoid leg of the alisphenoid; and the profundus certainly lies posterior to the basisphenoid leg of that bone. What the relations of the trochlearis and oculomotorius are to this latter leg is not evident, for there is nothing in the continuous membrane to in any way indicate the alisphenoid region. In teleosts, where, as in Scorpaena, this membrane of Amia may be replaced by bone, the relations of these two nerves to the basisphenoid leg of the alisphenoid are also not evident; for although, in my descriptions of Scomber, I stated that, in that fish, the trochlearis issued along the antero-mesial edge of the alisphenoid, a reconsideration of the figures makes it evident that the so-designated edge of the bone is, in reality, part of its ventral edge. These two nerves, in teleosts, thus both seem to have been pushed downward, by the growing ventral edge of the alisphenoid, and to lie, in the adult, simply ventral to that bone, without positively evident anterior or posterior relations to it.

In Gasterosteus, where, according to Swinnerton, the alisphenoid is wanting, a dorsal prolongation of the ascending process of the parasphenoid has invaded the region of the parasphenoid leg of the alisphenoid, and there has come into sutural contact with the closely adjacent ventral edge of the ventral process of the frontal. This condition of the parasphenoid is also found in Cottus octodecimospinosus, and will be fully described when describing that fish. It is apparently also found in the Barbidae and Cobitiidae, and in Homaloptera (Sagemehl '91, p. 564).

SPHENOTIC.

The sphenotic (postfrontal, postorbital ossification) is an irregular bone that forms the summit of the postorbital process of the skull. It forms part of the inner as well as part of the outer surface of the brain case. Its outer surface has lateral, dorsal and anterior regions, separated by sharp angles. The anterior surface forms part of the hind wall of the orbit. On it there is a relatively large recess, beneath a thin flange of bone, and from this recess the oticus canal leads upward laterally and backward in a curved course, traversing the bone and issuing on its dorsal surface near its hind end. It transmits the ramus oticus lateralis, accompanied by both communis and general cutaneous fibers, and is the homologue of the similar canal described by me in Scomber. On the lateral surface of the bone there is a large articular facet for the anterior head of the hyomandibular, the ventral portion of the facet being formed by the proötic. Immediately dorso-anterior to this facet there is a roughened surface which gives origin to the levator arcus palatini, and immediately dorso-posterior to the facet there is a depression, open posteriorly, which forms the anterior part of the dilatator fossa. The dorsal surface of the bone, which is flat, gives support to the postfrontal bone and also to the anterior edge of the pterotic and the lateral edge of the posterior portion of the frontal. The internal surface of the bone is relatively small, and presents, as in Scomber, two deep recesses separated by a thin and nearly vertical partition of bone which, projecting backward and mesially into the cranial

cavity, forms the dorsal portion of the anterior wall of the labyrinth recess. The posterior recess on the internal surface of the bone thus forms part of the labyrinth recess, but it lodges, in the adult, no part of the membranous ear, lying wholly dorso-anterior to the curved anterior edge of the anterior semicircular canal. The anterior recess forms the latero-postero-dorsal corner of that part of the cranial cavity that lies between the labyrinth and fore-brain recesses, and would accordingly seem to be a mid-brain recess.

Ridewood says ('04a, p. 56) that the sphenotic is found distinct from the postfrontal in but a few fishes. I, on the contrary, find these two bones almost invariably distinct and separate. Ridewood further says that the sphenotic is an endosteal ossification „set up in sympathy with" that ossification in the dermal tissues that gives origin to the postfrontal; and he accordingly considers the name sphenotic redundant. This relation of these two bones to each other I do not consider as established.

In the Barbidae, according to Sagemehl ('91, p. 573), the anterior semicircular canal may be enclosed in a canal in the sphenotic. This semicircular canal thus has this relation to the sphenotic in the Barbidae, while in Elops, as I have already stated, it traverses a canal in the alisphenoid.

Swinnerton, in his descriptions of Gasterosteus, uses the term „postorbital process" in a manner that might be confusing. On p. 532 of his work on that fish he says „the postorbital process, which in other teleosts forms part of the alisphenoid, remains unossified". The process of Gasterosteus here referred to is an outgrowth of the auditory capsule which projects forward in the dorsal portion of the hind end of the orbit, and is accordingly more properly an orbital or supraorbital process, than a postorbital one; and it is the lateral corner of its base, alone, that is the postorbital process, as that term is commonly used, and it ossifies in Gasterosteus, as in other fishes, as the sphenotic.

BASISPHENOID.

The basisphenoid is, as usual, T-shaped, the ventral end of its pedicle abutting against a median nodule of cartilage that lies on the dorsal surface of the parasphenoid. The anterior edge of the pedicle is strongly curved, running at first forward and downward, or sometimes even directly forward, and then curving downward, and downward and backward. The dorsal portion of the pedicle is usually expanded into a relatively large median plate, and this part of the pedicle is often independent of the ventral portion, touching and being bound to that portion, but not being continuous with it; the pedicle of the bone thus being in two, and sometimes even in three separate pieces. The pedicle, as usual, separates the anterior opening of the myodome into two parts, and its anterior edge gives insertion to the hind edge of the ventral portion of the membranous posterior portion of the interorbital septum.

The body of the basisphenoid is almost flat, and occupies a nearly horizontal, transverse position. Its posterior edge, on either side, is overlapped ventrally by, and lies against the dorsal surface of a small process of the prepituitary portion of the mesial process of the proötic, these small prepituitary processes of the proötics of opposite sides meeting in the middle line and thus shutting off the basisphenoid from the anterior edge of the pituitary opening of the brain case. In Scomber (Allis, '03), the basisphenoid forms part of the anterior edge of the latter opening. In Amia the anterior edge of the opening is formed by a transverse bolster of cartilage, the actual anterior edge of the pituitary fossa being, however, formed of membrane only.

In 45 mm Scorpaenas the basisphenoid is just beginning to form, appearing as a thin gutter-shaped lamina of bone in the midst of the dense fibrous tissues which form the floor of this part of the cranial cavity and the roof of the anterior portion of the myodome. Immediately anterior to this little bone there is a small median nodule of cartilage which lies between the extreme hind ends of the recti inferior muscles, imbedded in the anterior end of a median vertical band of tough fibrous tissue which gives origin to those muscles and will be further described when describing the myodome. This little nodule of cartilage is connected, antero-ventrally, by a delicate median line of cartilage, with the nodule of cartilage on which, in the adult, the pedicle of the basisphenoid rests, and this latter nodule is connected anteriorly, also by a delicate line of cartilage, with the cartilage of the interorbital septum. The pedicular line of cartilage together with the dorsal nodule thus form a basisphenoid cartilage which must certainly be the somewhat reduced homologue of the transverse prepituitary bolster of Amia. The basisphenoid bone of the adult Scorpaena is thus probably a perichondrial ossification related to this basisphenoid cartilage of the young Scorpaena, but it certainly extends beyond the cartilage, into the adjacent tissues, these tissues representing, in part at least, parts of the primary membranous cranium that have not chondrified.

PROÖTIC.

The proötic (petrosal) has lateral and orbital surfaces, the former forming a considerable part of the side wall of the brain case, and the latter a small part of the hind wall of the orbit. The bone is bounded dorsally by the sphenotic and pterotic, antero-mesially by the alisphenoid, and posteriorly by the exoccipital and basioccipital; with all of which bones it is either in contact or in synchondrosis. Its hind edge is, in part, slightly overlapped externally by the anterior edge of the opisthotic. Its ventral edge is overlapped externally by the lateral edge of the parasphenoid. The prepituitary portion of its mesial process suturates with the basisphenoid and alisphenoid.

The angle separating the lateral and orbital surface of the bone forms the ventral portion of the postorbital process of the skull, and on the dorsal end of this part of the bone lies the ventral portion of the anterior articular facet for the hyomandibular. The hind edge of this facet is raised to form a ridge which ends, at the dorsal edge of the bone, as a pronounced process, and this process, as already stated, gives origin to certain of the levator muscles of the branchial arches. The process lies between the articular facets for the anterior and posterior heads of the hyomandibular, and abuts against the inners urface of the hyomandibular between its two articular heads, the hyomandibular being often here perforated by a circular opening due doubtless to wear. Immediately posterior to the ridge and process, there is, on the lateral surface of the bone, a marked depression or pit, which, as already described, also gives origin and lodgment to certain of the levator muscles of the branchial arches. In one specimen the pit was unusually deep, and at the bottom of it there was a smaller pit, which gave insertion to one of the levator muscles, doubtless the internus anterior. This smaller pit in this one specimen extended forward into the postorbital process, and perforating the proötic, near its edge, was bounded mesially by the sphenotic, a thin plate only of that bone separating it from the cerebral recess for the anterior semicircular canal.

The angle that separates the lateral and orbital surfaces of the proötic is traversed by a canal which is the homologue of the more extensive trigemino-facialis chamber of my descriptions of Scomber. The nervus facialis issues from the posterior opening of this chamber, and the trige-

minus, lateralis trigemini and ciliaris profundi nerves from its anterior opening. The chamber lodges the trigeminus portion only of the trigemino-facialis ganglionic complex, together with the associated sympathetic ganglia, a recess on the cerebral surface of the bone lodging the lateralis and communis portions of the ganglionic complex. The chamber might accordingly be more properly called the trigeminus or semilunar chamber, the recess on the cerebral surface of the bone being called the facialis or geniculate recess. But until the manner of development is better known, of this chamber and recess, from a single chamber lodging the entire ganglionic complex, as in Amia, it seems to me best to retain the name already given to the chamber in Scomber, and to call the recess the trigemino-facialis recess. The main sympathetic trunk, the jugular vein, the external carotid artery and the vessel x all traverse the chamber in Scorpaena, the chamber thus representing either the whole or a portion of the upper lateral chamber of the eye-muscle canal of Amia (Allis, '03, p. 94). Into the chamber two to four foramina open; a large trigeminus one, a slightly smaller facialis one, and two small foramina, one or both of which may be included in the large trigeminus foramen. One of the two small foramina, when found, transmits the ramus ophthalmicus lateralis, the other transmitting the truncus ciliaris profundi. The ophthalmicus foramen lies slightly dorso-anterior to the trigeminus foramen, this latter foramen lying anterior to the facialis foramen, while the profundus foramen lies in the internal jugular groove at a variable distance anterior to the trigeminus foramen. The trigeminus foramen transmits the radix trigemini, the ramus buccalis plus oticus lateralis and the encephalic branch of the jugular vein. The oculomotorius traverses a foramen that perforates the proötic anterior to these several foramina, as will be later described, and in one instance this nerve was accompanied, as it traversed its foramen, by the truncus ciliaris profundi.

Sagemehl says ('91, p. 568) that in the Cyprinidae the ramus ophthalmicus superficialis (trigeminus lateralis) always perforates the alisphenoid; and Stannius says ('49, pp. 33 & 36) that this same nerve pierces the alisphenoid (Keilbeinflügel) in most teleosts. Sagemehl further says ('84b, p. 70) that independent foramina for the truncus trigemini and the ramus ophthalmicus superficialis trigemini is a primitive condition, and that a single foramen for these two nerves is exceptional. Neither of these statements is true either for Scomber or Scorpaena, and it would seem as if the foramina referred to must be, as in Amia, the foramina by which the nerves referred to issue from a trigemino-facialis chamber and not those by which they issue from the cranial cavity to enter that chamber. That there is a radical difference in these two sets of foramina was pointed out in my work on Scomber, and will be further discussed in the course of the present work.

The ventral portion of the proötic of Scorpaena, the part that lies ventral to the mesial process of the bone, forms, as usual, the lateral wall of the myodome, and its ventral edge is edged its full length with a broad band of cartilage, this cartilage being held in a deep slit-like groove in the edge of the bone. This groove lies between thin external and internal laminae of the proötic, of perichondrial origin, the anterior edges of these laminae being united along the anterior edge of the bone. The anterior edge of the endosteal bone, thus formed, then receives membranous additions which prolong it anteriorly, especially in its dorsal portion. Ventro-mesial to this edge of the bone, the ventro-anterior corner of the edging band of cartilage is cut away to form a large incisure which bounds the passage for the internal carotid artery. Posterior to this incisure the ventral edge of the edging cartilage forms the lateral boundary of the hypophysial fenestra, the ventral edge of the cartilage being presented ventro-mesially and abutting against the lateral surface of the median ridge on the dorsal surface of the postorbital portion of the parasphenoid.

The ventral edge of this ventral portion of the proötic is overlapped externally by the lateral edge of the body of the parasphenoid, its anterior edge being in part overlapped externally by, and in part suturating with the hind edge of the ascending process of the same bone. In the angle between the ascending process and the body of the parasphenoid, between that bone and the proötic, is the internal carotid foramen, which leads from the external surface of the skull inward and forward between the parasphenoid and the proötic, and then across the internal carotid incisure, into the myodome. On the external surface of the proötic, and running from the dorsal edge of the internal carotid foramen upward and backward toward the facialis opening of the trigemino-facialis chamber, there is a slight groove which marks the course of the internal carotid artery before it enters the foramen. Immediately anterior to this groove, on the lateral surface of the ascending process of the parasphenoid, the infrapharyngobranchial of the first branchial arch is flexibly attached by strong fibrous tissues.

The mesial process of the proötic forms, as usual, part of the roof of the myodome and part of the floor of the cranial cavity. The angle between it and the ventral part of the bone forms the dorso-lateral angle of the myodome, and in this angle, near its anterior end, there is a deep pit leading upward in the bone almost to the floor of the trigemino-facialis chamber; a remnant, doubtless, of the passage which, in Amia, connects the ventral portion of the myodome with its upper lateral chamber. Immediately anterior to this pit is the ventral opening of the canal for the palatinus facialis, that canal beginning on the cerebral surface of the bone, in what has already been referred to as the trigemino-facialis recess. The canal lies wholly in a part of the bone that is of membranous origin, as will be later explained.

The dorso-lateral angle of the myodome is well rounded, and is continued forward upward and laterally to the internal jugular notch, where, turning backward, it falls into and is continuous with the anterior end of the internal jugular groove. The internal jugular notch, as already fully described when describing the alisphenoid, lies between the dorsal end of the ascending process of the parasphenoid and the ventral, process-like end of the anterior one of the two little ridges on the external surface of the alisphenoid, and the internal jugular groove, beginning there, runs backward and laterally along the orbital surface of the proötic into the ventral end of the trigeminus opening of the trigemino-facialis chamber. The slight ridge on the proötic that forms the ventral edge of the groove is closely applied, in its anterior portion, to the inner surface of the dorsal edge of the ascending process of the parasphenoid, while posteriorly it is continuous with the anterior edge of the lateral wall of the trigemino-facialis chamber. In the dorso-lateral angle of the orbital opening of the myodome, immediately mesial to the internal jugular notch, is the external opening of the oculomotorius foramen, that foramen lying wholly in the proötic. Dorsal to the internal jugular groove, on the orbital surface of the proötic, there is often a slight ridge with a process-like and downwardly projecting ventral end, exactly similar to the two ridges on the alisphenoid. The process-like end of this proötic ridge is, like the processes on the alisphenoid, connected by fibrous tissue with the dorsal edge of the ascending process of the parasphenoid, the process and tissue evidently representing an anterior extension of the lateral bounding wall of the trigemino-facialis chamber.

In Amia the lateral bounding wall of the trigemino-facialis chamber is well developed, being wholly of bone or cartilage, while the mesial wall is wholly of membrane. In Scorpaena, and also in Scomber, it is the mesial wall that is well developed, the outer wall being greatly reduced, while Lepidosteus presents a condition intermediate between Amia and Scorpaena.

The mesial process of the proötic of Scorpaena has, as it has in Scomber, anterior and posterior portions, the pituitary opening of the brain case lying between the two portions. Immediately posterior to the pituitary opening, a small process of the postpituitary portion of the main process, projecting mesially, suturates with a corresponding process of the opposite side. Posterior to this little suturating process the mesial edge of the main process is connected by synchondrosis, by a median interspace of cartilage, with its fellow of the opposite side. On its dorsal surface, this interspace of cartilage is considerably wider than on its ventral surface, a thin lamina of the ventral layers of the process of the proötic projecting mesially, nearly to the middle line. Posteriorly, the interspace of cartilage is continuous, along the hind edge of the proötic, with the cartilage that caps the ventral edge of the bone, the hind edge of these united bands of cartilage bounding the anterior end of the basioccipital and connecting that bone, by synchondrosis, with the proötic. The anterior boundary of the pituitary opening is formed by a small sharp process of the prepituitary portion of the mesial process of the proötic. This little process lies, as already stated, against the ventral surface of the hind edge of the basisphenoid, and usually extends to the middle line of the skull, where it suturates with its fellow of the opposite side, thus completely cutting off the basisphenoid from all bounding participation in the pituitary opening. Antero-dorsal to this little pituitary process of the prepituitary portion of the entire process, the process suturates with the basisphenoid and the alisphenoid, as in Scomber.

The pituitary opening of the brain case of Scorpaena is closed, in the recent state, by membrane, this membrane being slightly concave on its dorsal surface, and slightly convex on its ventral surface. A slight depression is thus formed in the floor of the cranial cavity, this depression underlying the pituitary body and being the pituitary fossa. The pituitary opening of the brain case of the adult Scorpaena is, accordingly, the functional equivalent of the so-called pituitary fossa (Swinnerton), or pituitary space (Parker) of teleostean embryos: and an opening, similar to this one in Scorpaena, must certainly be found, at some stage, in all fishes the adults of which possess a basisphenoid bone. But the opening, though shown in certain figures of median sections of the teleostean skull, has seldom been particularly described. In Scomber I fully described it, using the word opening in place of fenestra so as to avoid, as much as possible, any suggestion of an homology.

On the internal surface of the proötic, near the sutural corner between this bone, the alisphenoid and the basisphenoid, is the internal opening of the foramen for the nervus oculomotorius. Posterior and slightly lateral to the pituitary opening the mesial process of the bone is perforated by the foramen for the nervus abducens, that nerve passing from the cranial cavity directly into the myodome. Lateral to these two foramina are the internal openings of the trigeminus, facialis, profundus and palatinus foramina; the first three foramina piercing the body of the bone to enter the trigeminofacialis chamber, while the palatinus foramen perforates the base of the mesial process of the bone and so enters the myodome. All four of these foramina lie in what is, in some specimens, a simple depression, but in others a marked recess on the internal surface of the bone. The hind wall of this recess looks postero-laterally and forms part of the anterior wall of the labyrinth recess, that wall being represented, both dorsal and ventral to the pocket, by a low ridge of bone; the dorsal ridge being continuous dorsally with the flange of bone that separates the two recesses on the internal surface of the sphenotic, and the ventral ridge vanishing along the mesial boundary of the saccular groove. The roof of the recess is formed by a nearly horizontal, shelf-like web of bone which extends across the angle that lies between the anterior wall of the labyrinth recess and the body of the proötic

anterior to that wall. A much smaller but similar web of bone may separate the recess into dorsal and ventral portions, the facialis and palatinus foramina leading, in such cases, from the ventral portion of the recess, and the trigeminus and profundus foramina from its dorsal portion. The recess lodges the profundus ganglion and also the lateralis and communis portions of the trigemino-facialis ganglionic complex. The recess can accordingly be called the trigemino-facialis recess, although, as already stated, geniculate recess might be a more proper designation.

The canal for the ramus palatinus facialis thus perforates, in Scorpaena, the base of the mesial process of the proötic and does not enter the trigemino-facialis chamber in any part of its course; and this is the condition found also in the Characinidae (Sagemehl, '84 b, p. 65) and Cyprinidae (Sagemehl, '91, p. 558). In Scomber, on the contrary, the nerve first enters the trigemino-facialis chamber and then pierces the proötic to enter the myodome (Allis '03). In Trigla Lepidotrigla and Dactylopterus, as will be later shown, the nerve also first enters the trigemino-facialis chamber, but instead of then piercing the proötic by a separate canal, as in Scomber, it simply issues by the trigeminus opening of the chamber and so enters the orbit. In Menidia, the nerve is said by Herrick ('99, p. 176) not to enter the myodome (sub-cranial canal), butto run „along the outer side of the canal, not the inner"; thus apparently being either as in Scomber, or as in Trigla Lepidotrigla and Dactylopterus.

Immediately posterior to the trigemino-facialis recess, the labyrinth recess begins, and in that recess, on the internal surface of the proötic and immediately dorso-postero-lateral to the trigemino-facialis recess, there are two adjoining depressions, the anterior one lodging the ampulla of the anterior semicircular canal, and the posterior one the ampulla of the external canal. Ventro-mesial to these depressions, and immediately posterior to the ventral portion of the trigemino-facialis recess, a large and deep longitudinal groove begins, and, extending backward to the hind end of the proötic, immediately dorsal to the base of the postpituitary portion of the mesial process of the bone, forms the anterior portion of the saccular groove. The bottom of this groove is thin, and this part of the proötic forms, on the outer surface of the skull, the anterior part of the bulla acustica.

The conditions in the proötic region of 45 mm specimens, examined in serial sections, must now be considered. In these specimens, the basisphenoid bone is just beginning to develop, and lies immediately posterior and ventral to the posteriorly directed dorsal end of the basisphenoid cartilage. Excepting only this little bone and cartilage, the floor of the cranial cavity is, at this age, wholly membranous from its anterior end back to the abducens foramina. Immediately posterior to the abducens foramina, the cranial floor is formed by a horizontal bridge of cartilage which corresponds exactly, in extent and position, to the bony bridge formed by the united mesial processes of the proötics of the adult Amia. But the saccus vasculosus lies, both in these 45 mm specimens and also in the adult Scorpaena, on the dorsal surface of this proötic bridge, while in Amia it lies (Allis, '97 a, pp. 494 und 505) ventral to that bridge. As the bridges in these two fishes are unquestionably homologous, this difference in the position of the saccus, if the sacci also are homologous, must be caused by its being, in Scorpaena, pulled out from beneath, and lifted up above the bridge, by the greatly developed hypoaria; the saccus thus being pulled out of the myodome and so losing all relation to that canal.

Those parts of the mesial processes of the proötics of the adult Scorpaena that lie anterior to the abducens foramina are thus not preformed in cartilage, and must accordingly be developed wholly in membrane, as I was led to conclude, in an earlier work ('97), that they must be in all teleosts.

The membrane in which they develop is, in my 45 mm specimens, a thick layer of coarse fibrous tissue which extends from the opticus to the abducens foramina, passing on either side of the pituitary fossa. This membrane is continuous, on either side, with the side wall of the skull, the ventral and larger portion of that wall here being also of membrane. This latter membrane is attached dorsally to the ventral edge of a cartilaginous process of the auditory capsule which forms the dorso-lateral corner and the dorsal portion of the side wall of this part of the skull. This process is called by Swinnerton ('02), in his descriptions of Gasterosteus, the postorbital process of the auditory capsule; but, as already stated, supraorbital process would seem a better term, for the process extends antero-mesially from the postorbital process of the skull along the dorsal edge of the posterior portion of the orbit. The membranous side wall of the skull ventral to this process is, in my 45 mm specimens, undergoing ossification to form parts of the proötic and alisphenoid bones, and the former bone, or that part of the membrane that will ossify as part of it, is perforated, immediately ventral to the ventral edge of the cartilage, by two foramina. One of these foramina is a large opening which transmits the united trigeminus and lateralis trigemini nerves and also the encephalic branch of the jugular vein, the other transmitting the facialis and lateralis facialis nerves. Ventro-anterior to these two foramina, but still posterior to the slightly developed basisphenoid bone, the membrane is pierced by both the oculomotorius and truncus ciliaris profundi; these two perforations lying relatively close together, the one for the ciliaris profundi slightly dorso-posterior to the one for the oculomotorius.

In the region ventral to the profundus foramen the membranous cranial wall is connected by a bridge of dense, coarse, fibrous tissue, with the dorsal end of the ascending process of the parasphenoid, that part of the latter process that is cut in sections passing through this region, forming the lateral wall of the orbital opening of the myodome and lying anterior to the cartilage that represents the ventral portion of the proötic. The dorsal end of the process of the parasphenoid here lies at a relatively considerable distance from the membranous side wall of the cranial cavity, and from its anterior edge, and continuous with the bridge of fibrous tissue that spans the space between it and the membranous cranial wall, a strong line of tissue runs dorsally, and, separating into two parts, has its attachment to the cranial wall, one part dorsal and the other ventral to the ophthalmic nerves. This line of tissue lies wholly anterior to the truncus maxillo-mandibularis trigemini, and represents, in part, the two little process-like ridges on the external surface of the alisphenoid of the adult, and, in part, the fibrous or connective tissues that extend from those little processes to the dorsal end of the ascending process of the parasphenoid. The line of tissue that has its insertion dorsal, and hence morphologically postero-lateral, to the ophthalmic nerves, represents the postero-lateral one of the two processes of the adult, the line that has its insertion ventral, and hence morphologically antero-mesial to the nerves, representing the antero-mesial process: the two bands of tissue together representing the parasphenoid leg of the alisphenoid, here pierced by the ophthalmic nerves, as the pedicle of the alisphenoid is in Amia. The basisphenoid leg of the alisphenoid is represented in an undefined portion of this part of the cranial wall, that wall being of membrane in its ventral portion, but already ossified in its dorsal portion. The bridge of fibrous tissue that spans the space between these two legs of the alisphenoid, represents that part of the orbital surface of the proötic of the adult that is occupied by the internal jugular groove.

Slightly posterior to the oculomotorius and profundus foramina the lateral edge of the bridge of fibrous tissue above referred to sends a line of tissue downward internal to, and parallel to the

bony ascending process of the parasphenoid, this line of tissue edging the anterior edge of the plate of cartilage that represents the ventral portion of the proötic and then passing downward along the external surface of that cartilage. From the mesial edge of the bridge of tissue, and from the membranous cranial wall posterior to it, another line of tissue descends, passing along the internal surface of the proötic cartilage. Between the two descending lines of tissue, anteriorly, and between the proötic cartilage and the internal line of tissue posteriorly, a space is left, which, in the 45 mm specimens, is filled with fat globules and loose connective tissue. This space lies immediately beneath the trigemino-facialis chamber, and its dorsal wall ossifies to form the thin bony floor of that chamber. In its anterior portion the space is tall, extending from the floor of the trigemino-facialis chamber downward beyond the line of origin of the mesial process of the proötic; that process here being wholly of membrane, and rising perpendicularly from the membranous mesial wall of the space. Slightly posterior to this, in those sections that cut through the trigeminus foramen, the fat space separates into dorsal and ventral limbs. The dorsal limb continues backward immediately beneath the floor of the trigemino-facialis chamber and extends to the hind end of that chamber. The ventral limb extends backward to the hind end of the proötic cartilage, lying always opposite the line of origin of the membranous portion of the mesial process of the proötic, but passing ventral to the cartilaginous portion of that process and there occupying the dorso-lateral corner of the myodome. The lateral wall of the dorsal limb of the space is always formed of membrane or of membrane bone. The lateral wall of the ventral limb is always of cartilage, this limb of the space lying in a wide and shallow groove on the inner surface of the proötic cartilage, the dorsal edge of the groove being marked by a sharp edge or ridge.

This space in the proötic evidently has some special morphological significance, for, although not evident in the adult Scorpaena, it quite certainly has its homologue in an important vacuity found in the proötic of the adults of certain other teleosts, as will later be shown when describing the myodome in Gadus. It may be referred to as the proötic vacuity. The mesial wall of the anterior part of the vacuity is, in the 45 mm Scorpaena, a direct ventral continuation of the mesial wall of the trigemino-facialis chamber, the lateral wall of this anterior part of the vacuity being similarly related to the lateral wall of that chamber.

Close to the anterior end of the proötic vacuity, in the 45 mm Scorpaena, the ramus palatinus facialis pierces the membrane that later ossifies as the mesial process of the proötic, near the base of that process, and passing internal to the anterior edge of the proötic cartilage enters the myodome. The nerve arises from the intracranial communis ganglion, and does not in any part of its course enter the trigemino-facialis chamber. In the intracranial part of its course, it lies along the cerebral surface of a membranous portion of the cranial wall, imbedded in loose connective tissues, these same tissues also enclosing, mesially, the intracranial portion of the trigemino-facialis ganglion, and being prolonged dorsally as part of the cerebral wall of the labyrinth recess. This tissue may therefore represent the tough glistening membrane that, in Amia, forms the lateral bounding wall of the cranial cavity in the pituitary region, though it seems more probable that that membrane is represented, in Scorpaena, in the membrane that forms the mesial wall of the trigemino-facialis chamber. Following Sagemehl, I ('97) formerly considered the tough glistening membrane of Amia as a specially developed portion of the dura mater. My present work leads me to accept this conclusion only with the proviso that the dura mater is itself a differentiated portion of the membranous tissue that primarily forms the enclosing capsule of the central nervous system.

MYODOME.

The myodome (eye-muscle canal) of Scorpaena has the shape of a funnel, the body of which is triangular or semicircular in transverse section, while the tubular portion is nearly circular in section. The orbital opening of the canal is approximately an equilateral triangle with rounded corners, the base of the triangle being presented dorsally and the triangle being bisected by the pedicle of the basisphenoid. The opening is bounded ventrally by the body of the parasphenoid, laterally on either side by the ascending process of the parasphenoid, and dorsally mainly by the body of the basisphenoid though partly also by the prepituitary portions of the mesial processes of the proötics. At the extreme dorso-lateral corner of the opening, is the internal jugular notch, that notch lying, as already explained, between the basisphenoid and parasphenoid legs of the alisphenoid. From this notch the internal jugular groove leads postero-laterally into the trigeminus opening of the trigemino-facialis chamber, the notch, groove and chamber all being remnants of the upper lateral chamber of the myodome of Amia.

Immediately internal to its orbital opening the myodome expands abruptly at its dorso-lateral corners, a pocket thus here being formed, on either side, which, as already stated, projects upward and reaches the under surface of the thin floor of the trigemino-facialis chamber. The myodome here has its largest transverse section, and from here contracts rapidly to the hind edges of the proötics, where the long and relatively small tube of the funnel begins. This tube lies wholly in the grooved ventral surface of the basioccipital, the body of the funnel lying wholly between the proötics. Between the ventral edges of these latter bones, and also between the ventral edges of the groove in the basioccipital, there is a long slit-like opening, the hypophysial fenestra. This fenestra extends the full length of the floor of the myodome but is closed, ventrally, by the parasphenoid, excepting at its extreme hind end where the myodome opens onto the ventral surface of the skull. The roof of the body of the myodome is formed in part by the basisphenoid, but mainly by the mesial processes of the proötics, and it is perforated, in its anterior portion, by the median, pituitary opening of the brain case.

The pituitary opening is closed, in the recent state, by membrane, and, arising from this membrane and extending forward to the hind edge of the pedicle of the basisphenoid, there is a vertical band of tough fibrous tissue, attached by its dorsal edge to the ventral surface of the body of the basisphenoid. The anterior end of this tissue gives origin, on either side, to the rectus inferior muscle. The ventral edge of the band spreads, and is firmly attached to the dorsal edges of the recti interni muscles, those two muscles entering the myodome, on either side, ventral to the rectus inferior, along the floor of the myodome and close against the pedicle of the basisphenoid. The attachment of these recti interni to the ventral edge of the mid-vertical membrane seems to be the important origin of the muscles, for although they extend posteriorly considerably beyond the membrane, approximately to the hind ends of the proötics, they are, in this part of their course, simply attached to each other and to loose tissues in the myodome; the attachment of the muscles to each other being strong. The rectus superior, on either side, enters the myodome near the dorsal end of its orbital opening, there passing downward between the rectus inferior, mesially, and the rectus externus laterally. Running downward and but slightly backward it passes lateral to the rectus internus and has its origin on the dorsal surface of the parasphenoid. The rectus externus enters the myodome along the lateral edge of its orbital opening, lying lateral to all the other muscles.

Turning backward in the myodome it lies at first dorso-lateral to the rectus internus, but it extends posteriorly beyond that muscle, into the basioccipital part of the myodome. Near the hind end of this latter part of the myodome, the muscle becomes tendinous and is inserted on the basioccipital, certain of the fibers of the tendon passing out of the myodome, by its posterior opening, and there arising from the ventral, external surface of the bone. The orbital opening of the myodome is closed by a strong membrane which the recti muscles all perforate to reach their points of origin.

Sagemehl says that, in the Characinidae, the recti inferior and externus arise in the myodome, the internus having its origin in the orbit; and as the myodome, in the Cyprinidae, is said to differ in no important respect from that in the Characinidae, these muscles must there have the same origin. In all of the mail-cheeked fishes that I have examined, and also in Scomber (Allis, '03), it is the externus and internus instead of the externus and inferior that have this origin in the myodome.

CAROTID ARTERIES AND VESSEL X.

The external and internal carotid arteries were traced both in 45 mm specimens and in the adult, and they differ but little from the arteries in the adult Ophiodon elongatus, recently described by Allen ('05). I, however, find, in young specimens of Scorpaena, Trigla, Lepidotrigla and Dactylopterus, a small artery that is not described by Allen, that would seem to be in part the homologue of the hyo-opercularis artery of my descriptions of Amia ('97, p. 497), and that has already been referred to as the vessel x.

The external carotid of Scorpaena, after its origin from the short common carotid, runs upward and forward, enters the trigemino-facialis chamber through its facialis opening, and traversing that chamber issues by its trigeminus opening. It then immediately gives off what must be the sclerotic-iris artery of Allen's descriptions, though the artery as I find it has not exactly the distribution given by Allen. It then gives off a branch to the levator arcus palatini muscle and the large facialis-maxillaris artery, as described by Allen in Ophiodon, and itself turns downward and slightly backward in the V-shaped space between two flanges on the hind edge of the metapterygoid, to be later described. At the lower edge of the internal one of these two flanges the artery falls into the arteria hyoidea at a sharp bend in that artery, that part of the carotid that lies between the point where it gives off the facialis-maxillaris and the point where it falls into the arteria hyoidea, corresponding closely in position to the secondary afferent pseudobranchial artery of my descriptions of Amia ('00 c). The hind end of the latter artery, in larvae of Amia, closely approaches the dorsal end of the primary affferent pseudobranchial artery, which artery is the arteria hyoidea, and if the secondary afferent artery should acquire a connection with the arteria hyoidea, and that artery retain its connection with the pseudobranch, the conditions found in Scorpaena would arise. And this is quite certainly the manner in which the teleostean arrangement has actually arisen.

The arteria hyoidea of Scorpaena, coming upward along the ceratohyal, turns dorso-anteriorly along the anterior aspect of the interhyal and traverses a large opening that lies between the preopercular and the posterior process of the quadrate, posteriorly, and the symplectic anteriorly. There it immediately gives off the mandibular artery, which runs downward and forward, along the outer surface of the quadrate, into the mandible. Having given off this artery, the arteria hyoidea turns sharply upward, crosses the external surface of the hyomandibulo-symplectic interspace of cartilage and at the antero-dorsal corner of that cartilage passes inward through a small opening between the cartilage, the metapterygoid and the shank of the hyomandibular. Continuing its upward

course, the artery passes along the inner surface of the external one of the two flanges on the hind edge of the metapterygoid, there lying along the anterior edge of a part of the levator arcus palatini muscle that here has its insertion, and reaches the ventral edge of the internal one of the two flanges on the metapterygoid. There it turns sharply dorso-posteriorly, crosses the internal surface of the hyomandibular and enters the opercular hemibranch at about its dorsal third. At the bend it fuses with the ventral end of the external carotid, that artery forming, in direction, a direct dorsal continuation of that part of the arteria hyoidea that lies below the bend.

Allen ('05), in his work on Ophiodon, considers the hyoid artery as ending at the point where the mandibular artery is given off, the artery above that point being called by him the external carotid, with an afferent pseudobranchial branch arising from it. This manner of naming these arteries is based on the fact that, in Ophiodon, the so-called external carotid is so large, and the hyoid artery so small, that the flow of blood is said to be largely or wholly downward to the point where the mandibular artery arises, instead of upward from there, toward the hemibranch. In Amia, also, I was led to conclude ('00 c, p. 121) that the flow of blood in the dorsal portion of the arteria hyoidea must be downward, and be derived from the carotid through the pseudobranch. But granting that this be so, the nomenclature seems to me a faulty one, for the artery, up to the hemibranch, is certainly, in its development, the afferent pseudobranchial artery, or arteria hyoidea. Furthermore the course of this so-called part of the external carotid artery, as given by Allen in Ophiodon, is not exactly the same as that of the corresponding artery in Scorpaena, the artery being said by Allen (1. c., p. 51) to pass „over the dorsal edge of the hyomandibular", then, „along the inner side of the metapterygoid" until it receives the hyoid artery, after which it „comes to the outer surface through a foramen between the symplectic, hyomandibular, preopercular, and quadrate bones". In Scorpaena, this part of the external carotid of Allen's nomenclature passes downward between two flanges on the hind edge of the metapterygoid, then comes to the outer surface of the palato-quadrate through a small foramen between the metapterygoid and hyomandibular, and, remaining always on the outer surface of the apparatus, receives the hyoid artery which passes outward through an opening between the symplectic, quadrate and preopercular to join it. And in Cottus, Trigla and Dactylopterus strictly similar or equivalent conditions are found, as will be later described. In Scomber, also, this artery has the same course as in these several fishes: for, the connection of the external carotid and hyoid arteries not being given in my work on Scomber, I have had Mr. Henry examine it, in that fish, and he finds the arrangement exactly as above described for Scorpaena, excepting that the two sharp bends found in the hyoid artery (my nomenclature) of Scorpaena do not exist in Scomber; the artery in the latter fish having a nearly straight course as it runs upward from the hyoid arch toward the opercular hemibranch, and the external carotid falling into it at a right angle. This course of the artery in these several fishes seeming to make its course in Ophiodon exceptional, unless there were some error or misconception of its course in Allen's work, I had Mr. Allen reexamine it — for he was at the time attached to my laboratory — and the sketch sent me by him shows that the conditions in Ophiodon are similar to those in Cottus; the hyoid artery (my nomenclature) passing to the outer surface of the palato-quadrate apparatus between the symplectic and preopercular, then crossing the external surface of the hyomandibulo-symplectic cartilage and passing to the inner surface of the apparatus again between the hyomandibular and metapterygoid. Then the artery, to all appearance, runs upward along the inner surface of the hind edge of the metapterygoid as it does in Cottus; but, in Ophiodon, the two flanges on the hind edge of the metapterygoid

must lie, as they do in Cottus, and as will be later described, in practically the same plane, the internal flange lying wholly dorsal to the external one and the adjoining edges of the two flanges being fused excepting where they enclose a relatively large foramen which perforates the bone so formed. The hyoid artery, in Ophiodon, when it reaches the inner surface of the palato-quadrate, accordingly lies along the inner surface of what is, in reality, the external flange on the hind edge of the metapterygoid and not along the inner surface of the body of that bone. There it receives the external carotid artery (my nomenclature) which, coming down along the external surface of the internal flange on the hind edge of the metapterygoid, traverses the foramen between the ventral edge of that flange and the dorsal edge of the external flange. This is also the condition found in Cottus, and Allen's description of Ophiodon is here so particularly referred to simply because it is another of the numerous instances that show that when existing descriptions seem to indicate that important structures, in different animals, differ in their relations to each other, reexaminations and a proper understanding of the parts almost invariably show that such is not the case. There are however instances that do not seem capable of this interpretation. In Triton, for example, Coghill ('06) says that the ramus ophthalmicus profundus V passes dorsal to the ramus superior III, while in Amblystoma it passes ventral to that nerve. The supposition that the ophthalmicus V is a superficialis in Triton and a profundus in Amblystoma seems unwarranted, and even this would not explain the conditions found in one specimen of Triton, where Coghill says that the ophthalmicus V passes between two portions of the r. superior III, lying dorsal to one of them and ventral to the other.

In Scorpaena, the internal carotid artery, having separated from the external carotid, runs forward and downward in the groove on the outer surface of the proötic, and, traversing the internal carotid foramen enters the myodome across the internal carotid incisure. There it immediately gives off a branch which, on one side of the 45 mm specimen examined, is small, runs forward in the myodome and could there be traced but a short distance. On the other side of this specimen the branch is large, runs forward in the myodome along the internal surface of the ascending process of the parasphenoid, and, at the anterior edge of that process, sends a branch toward the efferent pseudobranchial artery (arteria ophthalmica magna), apparently joining it, and then continues forward as the orbito-nasal artery of Allen's descriptions of Ophiodon. This connection of these two arteries, if it actually exists, which could not be definitely established, would agree with that found by me in Amia. It was not found by Allen in Ophiodon (l. c., p. 55).

The efferent pseudobranchial artery arises from the opercular hemibranch and, running forward external to the cranium, terminates in the choroid gland of the eye-ball. Immediately anterior to the ascending process of the parasphenoid, and immediately anterior also to the point where, on one side of my specimen, the artery apparently receives a communicating branch from the internal carotid, it sends a branch downward and mesially, across the ventral edge of the rectus internus and dorsal to the parasphenoid, to join, in the middle line, a corresponding branch from the artery of the opposite side; a transverse commissure between the two arteries thus here being formed. The efferent pseudobranchial artery of Scorpaena thus differs in no respect from that in Ophiodon excepting that, on one side of my specimen, it apparently receives a communicating branch from the internal carotid.

In Pleuronectes, Cole and Johnstone ('01, p. 96) say that the two ophthalmic (efferent pseudobranchial) arteries „perforate the proötics together with the superior jugular veins, passing through the jugular foramina". The external carotids are said to break up along the ventral surface of the

skull, not, accordingly, traversing the so-called jugular foramen, which foramen is the facialis opening of the trigemino-facialis chamber of my descriptions. This course of these two arteries being so unusual, I have had it looked up both in Rhombus and Solea. In both these fishes the efferent pseudobranchial artery runs forward external to the cranium, the external carotid traversing the trigemino-facialis chamber, both arteries thus having exactly the same general course that they have in Scorpaena and that they are known to have in many other teleosts. That Pleuronectes forms an exception to this rule I greatly doubt, the particular specimen examined by Cole & Johnstone doubtless presenting an abnormality in the course of these two arteries, as it apparently does also in the absence of an encephalic artery arising from the transverse commissure that is said to connect the internal carotids of opposite sides.

The internal carotid of Scorpaena, having given off the orbito-nasal artery or the communicating branch to the efferent pseudobranchial artery, as the case may be, runs mesially and but slightly anteriorly along the floor of the myodome, lying immediately beneath the rectus internus muscle. Having reached the middle line of the head, the artery turns upward between the two recti interni muscles, there lying closely pressed against its fellow of the opposite side. Whether there is here an anastomosis of the arteries of opposite sides to form a single median encephalic artery, such as Allen describes in Ophiodon, or not, could not be determined; but there probably is, as, otherwise, there would be no circulus cephalicus in this fish. It may, however, here be stated that the diagrams ordinarily given of this circulus, and as given by Ridewood ('99) for Cottus and Trigla, are misleading, for there is not here a simple transverse commissure, such as there is for the efferent pseudobranchial arteries. There are two arteries, one on either side, which, running upward to enter the cranial cavity, lie close together and fuse in the middle line for a short distance, and then separate again as they enter the cranial cavity. The one or two arteries in Scorpaena, whichever it be, running upward enters the hind end of the median vertical band of fibrous tissue, already described, that arises from the hind edge of the pedicle of the basisphenoid and ends posteriorly in the fibrous tissues that close the pituitary opening of the brain case. Having traversed this tissue, the two arteries become distinct again, perforate separately the membrane that closes the pituitary opening of the brain case, along the hind edge of the basispheniod, and enter the cranial cavity, their further course not being traced.

In Scomber I have stated ('03, p. 93) that the internal carotid enters the cranial cavity along the anterior edge of the basisphenoid, there perforating the membrane that closes the orbital opening of the brain case. This marked difference in the relations of the artery to the basisphenoid, in this fish and in Scorpaena, has led me to reëxamine Scomber, and I find that my statement regarding that fish is an error, the artery there running up posterior to the basisphenoid, as it does in Scorpaena.

The vessel x was examined in sections of young specimens of Scorpaena, Trigla, Lepidotrigla and Dactylopterus, but the results obtained were so unsatisfactory that I am preparing material for a further study of it. It is so small a vessel that it was not looked for in any of the adults. In the sections examined of Scorpaena, Trigla and Lepidotrigla strictly similar conditions were found, while in Dactylopterus the vessel presented a slightly different arrangement.

In Scorpaena, Trigla and Lepidotrigla the vessel is formed by the union of what seem to be small arteries that arise in some sort of relation to the efferent arteries of the first three branchial arches. Running forward parallel and close to the common carotid, the vessel soon separates into two parts which may be called its internal and external branches. The internal branch

closely accompanies the internal carotid and could be traced as far as the internal carotid foramen, where it either fused with the internal carotid or vanished in the sections. The external branch closely accompanies the external carotid until it reaches the facialis opening of the trigemino-facialis chamber. There it separates slightly from the carotid, but enters and traverses the trigemino-facialis chamber, lying somewhat dorsal to the carotid. Issuing from the chamber, the vessel separates into three branches. One of these branches accompanies the sclerotic-iris branch of the carotid artery and passes into the cranial cavity with that branch of the latter artery that traverses the little foramen in the alisphenoid, already described. A second branch of the vessel closely accompanies that branch of the carotid that goes to the levator arcus palatini. The third branch turns backward and immediately gives off a small branch which accompanies that terminal portion of the carotid that runs downward to fall into the arteria hyoidea. The remainder of this third branch then continues backward along the side wall of the skull, joins the truncus hyoideo-mandibularis facialis and traverses, with that nerve, the facialis canal through the hyomandibular. Slightly before it enters the latter canal it sends a branch backward, this branch joining the ramus opercularis profundus facialis and going to the region of the adductor hyomandibularis and the adductor and levator operculi. The terminal portion of the third branch of the vessel x of these fishes, this branch being given off from the external artery after that artery issues from the trigemino-facialis chamber through its trigeminus opening, thus has a distribution similar to that of a branch of the hyo-opercularis of Amia given off before the artery enters the trigemino-facialis chamber. In Amia, in fact, this latter branch is the important part of the artery, and so led me to call it the hyo-opercularis, the part that enters the trigemino-facialis chamber appearing as a small branch only.

PTEROTIC.

The pterotic (squamosal) forms a small lateral portion of the dorsal surface, and the dorso-posterior portion of the lateral surface of the brain case, and the larger part of the lateral wall of the temporal fossa. The bone is bounded, as usual, by the sphenotic, proötic, exoccipital and epiotic with all of which bones it is in synchondrosis, and by the lateral extrascapular, parieto-extrascapular, frontal and postfrontal, with which bones it is in sutural contact. The opisthotic overlaps externally the outer surface of its postero-ventral portion. On its internal surface there is a large recess which leads into a canal which lodges the outer portion of the external semicircular canal.

On the dorsal surface of the bone, near its lateral edge, there is a prominent longitudinal ridge which ends posteriorly in a short sharp point which forms one of the spines of the lateral row. A thin flat posterior process projects backward from the dorsal half or two-thirds of the hind edge of the bone, and gives insertion to the dorsal end of the fibrous membranes that line the anterior and posterior surfaces of the opercular opening. Degenerate muscle fibers are found in the dorsal ends of these membranes. No portion of the trunk muscles arises from the process. On the dorsal edge of the process the lateral edges of the lateral extrascapular and suprascapular rest, but the process gives no support to the supraclavicular, such as Sagemehl describes in the Characinidae and Cyprinidae. On the lateral surface of the bone, close to its dorsal edge and extending nearly the full width of the body of the bone, there is an oval facet for the posterior articular head of the hyomandibular, the facet lying considerably dorsal to that portion of the bone that lodges the external semicircular canal. Dorsal to the anterior portion of this facet, a depression on the anterior edge of the bone forms the posterior portion of the dilatator fossa. The pterotic is traversed by the

main infraorbital canal, the canal lying immediately beneath the spinous ridge on the dorsal surface of the bone and lodging but one sense organ of the line, innervated by the ramus oticus. The preopercular canal joins the main infraorbital at the hind end of the section of canal enclosed in the pterotic, the pterotic thus containing no post-preopercular latero-sensory ossicle.

BASIOCCIPITAL.

The basioccipital has, on its dorsal, cerebral surface, two large longitudinal grooves, one on either side, these grooves occupying the entire dorsal surface of the anterior two-thirds of the bone, excepting only the narrow median and lateral portions that form the bounding walls of the grooves. Each groove is continued backward, as a recess, into the posterior third of the bone, the hind end of each recess almost reaching the conical surface of the median vertebra-like depression on the hind end of the bone. The posterior half or two thirds of the uncovered portion of each of these grooves is roofed by a mesial, nearly horizontal process of the exoccipital of its side, the grooves thus becoming large and deep recesses in the cranial floor. Each groove lodges the posterior portion of the sacculus of its side, the anterior portion of the sacculus being lodged in the saccular groove on the cerebral surface of the proötic. On the outer surface of the skull, the bounding wall of the basioccipital portion of the saccular groove forms the posterior portion of the bulla acustica.

On the dorsal surface of the basioccipital, between the hind ends of the saccular grooves, there is a small median pit, sometimes separated into two parts by a thin transverse partition, this partition inclining from the mouth of the pit downward and backward toward its point. The pit, whether simple or double, leads downward and backward almost to the point of the conical vertebra-like depression on the hind end of the bone, approaching that point so closely that it sometimes is separated from it by a thin layer, only, of bone. This small median pit is evidently the homologue of the cavum sinus imparis of Sagemehl's descriptions of the Characinidae and Cyprinidae, but it is, in Scorpaena, wholly uncovered, the hind edges of the mesial processes of the exoccipitals reaching only to its anterior edge and being restricted to roofing, on either side, a portion of the corresponding saccular groove. This latter groove, it may be noted, is relatively small in the Characinidae and Cyprinidae, its anterior end passing but slightly beyond the hind edge of the proötic; and the sacculi of opposite sides are, in those fishes, connected by a canalis communicans, not found in Scorpaena.

Posterior to the cavum sinus imparis, the narrow remaining portion of the dorsal surface of the basioccipital slopes downward and backward to the hind end of the bone, is slightly concave and forms a small bounding portion of the foramen magnum. On either side of the cavum sinus imparis, there is a roughened surface which gives support to a corresponding portion of the ventral edge of the exoccipital, and immediately anterior to this surface, on either side of the anterior end of the cavum sinus imparis, the basioccipital encloses a small nodule of cartilage, a remnant of the chondrocranium, which lies between it and the exoccipital. Anterior to this nodule of cartilage the thin lateral edge of the basioccipital, on either side, is in sutural contact with the ventral edge of the exoccipital; while the median ridge of the bone, which separates the saccular grooves, gives support to the mesial edges of the mesial processes of the exoccipitals, a small remnant of cartilage there intervening.

On the ventral surface of the basioccipital there is a deep longitudinal groove, nearly circular in transverse section. This groove lies between the bottoms of the saccular grooves, tapers gradually to its hind end, and forms the posterior portion of the myodome. It opens on the ventral surface

of the basioccipital by a narrow median slit-like opening, which extends the full length of the groove and forms the posterior half of the hypophysial fenestra. This fenestra, as already stated, is closed ventrally, excepting in its posterior portion, by the underlying parasphenoid, the hind end of the fenestra remaining uncovered, spreading somewhat, and so forming an opening which leads directly into the hind end of the myodome. On the lateral surface of the hind end of the bone, immediately dorsal to a horizontal plane through the center of the vertebra-like depression on that end, there is, on either side, a slight depression which gives insertion to the occipito-supraclavicular ligament. This ligament of fishes is said by Sagemehl ('84 b, p. 49) to be a differentiation of the perimuscular fascia of the adductor muscle of the shoulder girdle; but this adductor muscle, as described by Sagemehl in the Characinidae, is not found in Scorpaena, and I doubt greatly this origin of the ligament. The only muscle that at all resembles Sagemehl's descriptions of the adductor, is a flat, thin muscle band that arises from the hind edge of the skull and has its insertion on the occipito-supraclavicular ligament near its outer end.

The basioccipital is bounded anteriorly, on either side, by the proötic, with which it is in synchondrosis, and dorsally by the exoccipital with which it is partly in synchondrosis, and partly in sutural contact. Its ventral surface is overlapped externally and largely covered by the parasphenoid. Its hind end is wholly occupied by the deep conical vertebra-like depression.

EXOCCIPITAL.

The exoccipital is an irregular bone which forms part of the lateral surface and part of the posterior surface of the brain case, this latter portion having a medullary prolongation. The angular edge that separates these two portions of the outer surface of the bone has, at about the middle of its length, a pronounced reëntrant and usually well rounded angle. Anterior to this angle the edge extends dorso-anteriorly and, reaching to the level of the floor of the hind end of the temporal fossa, forms the ventral portion of the lateral bounding wall of the posterior opening of that fossa. Posterior to the angle, the edge extends posteriorly and but slightly downward, and is thickened to form, at its hind end, an articular head, which looks posteriorly and slightly ventro-mesially, articulates with a process on the anterior edge of the first vertebra, and may be called the condylar process of the bone. The ventral surface of this condylar process is roughened, and rests directly upon the lateral portion of the dorsal surface of the hind end of the basioccipital, the two bones enclosing, at the anterior end of this suturating surface, the little nodule of cartilage already referred to when describing the basioccipital. Anterior to this part of the exoccipital, the ventral edge of the bone is a thin plate which rests upon and slightly overlaps externally the dorsal edge of the thin lateral portion of the basioccipital, the two bones forming the lateral wall of the saccular recess of the cranial cavity.

That part of the exoccipital that forms part of the posterior surface of the skull is presented dorso-posteriorly and is separated into two parts by a ventral continuation of the epiotic ridge, that ridge forming the mesial boundary of the posterior opening of the temporal fossa. The medullary prolongation of this part of the bone looks dorso-laterally, arches over the canal for the medulla oblongata, and is in contact, in the median line, with its fellow of the opposite side. This contact is by thin external and internal laminae of bone, the space between these laminae being filled with cartilage. Extending obliquely across this part of the bone there is a marked thickening which begins below and extends dorso-posteriorly, presenting a process-like appearance and strongly suggesting a vertebral arch here fused with the exoccipital. The dorsal end of this process-like thickening forms

the posterior portion of the dorso-mesial edge of the medullary prolongation; and the posterior portion of the ventral edge of the spina occipitalis is wedged in between the ends of the processes of opposite sides. Anterior to these process-like portions of the exoccipitals the ventral edge of the spina occipitalis rests on the external surface of the suturating edges of the exoccipitals. In the hind edge of the medullary prolongation of the exoccipital, there is a large semicircular notch, but it is closed with fibrous tissue and does not give passage to any structure.

From the internal surface of that part of the exoccipital that lies immediately dorsal to the saccular groove, a stout plate-like process projects mesially and slightly downward, and expanding slightly at its mesial end is in synchondrosis, in the middle line of the head, both with its fellow of the opposite side and with the dorsal edge of that thin median ridge of the basioccipital that separates the saccular grooves; a remnant of cartilage intervening between the three bones. The process forms the roof of a considerable portion of the saccular recess, but does not roof any portion of the cavum sinus imparis, as Sagemehl says that it does in the Characinidae and Cyprinidae, the hind edge of the process only reaching to the anterior edge of that pit. Immediately dorsal to the base, or line of origin, of this mesial process, the exoccipital is perforated by two foramina, one of which lies near the anterior edge of the process, and the other near its posterior edge. The anterior foramen opens on the lateral surface of the bone and transmits the nervus vagus, the other opening on the base of the condylar process of the bone, being sometimes double, and transmitting the occipital nerves. Slighty anterior to the vagus foramen the bone is perforated by the glossopharyngeus foramen. On the internal surface of the bone, immediately dorso-anterior to the vagus foramen, there is a recess which lodges the ampulla of the posterior semicircular canal. From this recess two canals start, one running upward and enclosing a portion of the membranous posterior semicircular canal, while the other runs latero-anteriorly and encloses part of the external canal. The canal for the external semicircular canal lies antero-internal to the angular edge between the lateral and posterior surfaces of the bone, the canal for the posterior canal lying in the ridge that forms a ventral prolongation of the epiotic ridge.

The exoccipital is bounded ventrally by the basioccipital, anteriorly by the proötic, dorso-laterally by the pterotic, and dorsally by the epiotic and supraoccipital, from all of which bones it is largely separated by lines of cartilage. The opisthotic overlaps externally the dorsal portion of the lateral surface of the bone, fitting into a depressed region on that surface.

OPISTHOTIC.

The opisthotic (intercalar) is a small plate-like bone, quite unquestionably of purely ectosteal origin, which forms the middle portion of the postero-lateral edge of the skull; there overlapping externally the adjoining edges of the pterotic and exoccipital, and extending forward to, or even slightly overlapping the hind edge of the proötic. Its hind edge is thickened and projects backward beyond the pterotic and exoccipital, there forming part of the lateral wall of the temporal fossa. A small eminence on this edge gives support, and is bound by ligamentous tissue to the ventral end of the opisthotic process of the suprascapular.

EPIOTIC.

The epiotic (exoccipitale) is a somewhat pyramidal bone which caps the dorso-mesial corner of the hind end of the temporal fossa and has dorsal, posterior, lateral and cerebral surfaces. A portion

of its dorsal surface gives support to the overlying parieto-extrascapular, the remaining part of that surface forming the lateral portion of the floor of the supratemporal pocket; this latter part of the bone, as already explained, lying on and appearing as a part of the posterior surface of the skull. The posterior surface of the bone forms part of the posterior surface of the skull; its lateral surface forming the mesial wall of the temporal fossa. The angle between these two latter surfaces forms a strong, epiotic ridge, which lies in a nearly vertical position near the middle of the corresponding half of the posterior surface of the skull, forms the mesial boundary of the posterior opening of the temporal fossa, and, with its ventral prolongation on the posterior surface of the exoccipital, marks the course of the posterior semicircular canal. The summit of the bone is directed dorso-postero-laterally, and from it a flat, and often sharp and slender process arises, directed postero-laterally and slightly ventrally. On the dorsal surface of this process, between it and the overhanging posterior portion of the parieto-extrascapular, the epiotic process of the suprascapular rests, the two processes roofing the hind end of the temporal fossa. The cerebral surface of the bone is wholly occupied by a deep conical pit which forms part of the labyrinth recess and lodges the dorsal portion of the posterior semicircular canal, that canal piercing the ventro-posterior wall of the recess and from there running downward through the bone, internal to the epiotic ridge.

The epiotic is bounded antero-laterally by the pterotic, ventrally by the exoccipital, and mesially by the supraoccipital, with all of which bones it is in synchondrosis.

SUPRAOCCIPITAL.

The supraoccipital forms part of the dorsal and part of the posterior surface of the skull, these two parts, or limbs of the bone lying at an obtuse angle to each other. From the postero-ventral limb of the bone, and extending its full length, a large thin spina occipitalis projects directly backward, the ventral edge of the spina lying partly upon, and partly being enclosed between, the adjoining dorso-mesial edges of the medullary prolongations of the exoccipitals. The dorsal limb of the bone projects forward between the lateral fontanelles in the roof of the primordial cranium, and is overlapped anteriorly by the frontals, and laterally, on either side, by the parieto-extrascapular. Between these three overlapping bones, a small and variable portion of the supraoccipital is exposed on the dorsal surface of the skull and forms part of the floor of the subquadrangular groove on the vertex. A strong transverse ridge, projecting dorso-posteriorly, crosses the hind edge of the dorsal surface of the bone, and against the anterior surface of this ridge the mesial processes of the parieto-extrascapulars rest. The postero-ventral limb of the bone is crossed, near its dorsal end and on either side of the spina occipitalis, by a more or less prominent transverse ridge, and that part of this limb of the bone that lies dorsal to this ridge forms, on either side, the mesial portion of the supratemporal pocket. The cerebral surface of the bone forms median portions of the roof and hind wall of the cranial cavity. The bone is bounded ventrally by the exoccipitals, and laterally, on either side, by the epiotic, with all of which bones it is in synchondrosis. Anteriorly the bone is edged with a band of cartilage, anterior to which the lateral fontanelles of opposite sides are confluent; the band of cartilage representing all that is found, in this fish, of the large postepiphysial cartilage of Scomber.

CRANIAL CAVITY.

The cranial cavity extends forward to about the middle of the orbit. The mid-longitudinal line of the floor of the cavity slopes downward and backward from its anterior end to the anterior

end of that thin median ridge-like portion of the basioccipital that separates the saccular grooves, and that supports, on its dorsal edge, the mesial edges of the mesial processes of the exoccipitals. There, the mid-longitudinal line of the floor changes abruptly in level, the immediately posterior portion lying at a slightly higher level, in a nearly horizontal position, on the dorsal surface of the platform formed by the united mesial processes of the exoccipitals. Posterior to this platform the floor slopes into the cavum sinus imparis, posterior to which there only remains the narrow edge of bone that forms the ventral bounding edge of the foramen magnum.

The thin raised platform formed by the united mesial processes of the exoccipitals lies on a level with the pituitary opening of the brain case, and under this platform, on either side, lies the posterior portion of the large saccular groove. Anterior to the exoccipital platform the saccular grooves diverge, on either side, the central portion of the floor of the cavity widening gradually from a thin median line at the edge of the platform, to its widest portion, immediately anterior to the anterior ends of the saccular grooves. At either lateral corner of this widest portion lies the trigemino-facialis recess, in which are the facialis, trigeminus, palatinus and profundus foramina, and approximately between these recesses, in the median line, is the pituitary opening of the brain case. Between the recess of either side and the anterior end of the corresponding saccular groove, there is a thin bony partition which forms the ventro-mesial portion of the anterior wall of the large labyrinth recess, that wall extending from there antero-dorso-laterally across the proötic and sphenotic. In the lateral wall of the labyrinth recess there are four small recesses, all related to the semicircular canals, and all separated from each other, and more or less surrounded by important cartilaginous remnants of the chondrocranium. In the bottom of the anterior one of these four recesses there are two depressions, separated by a low rounded ridge. The ventro-mesial depression lies in the proötic and lodges the ampulla of the anterior semicircular canal, the dorso-lateral depression lying in the sphenotic and being related to the rounded antero-dorsal corner of the anterior semicircular canal, that canal lying wholly exposed in the cranial cavity. The next posterior one of the four recesses also has two portions, one of which lies in the proötic and lodges the ampulla of the external semicircular canal, while the other portion leads into the pterotic and encloses the lateral portion of the same canal. The postero-ventral recess has three portions, a little pit-like depression in the exoccipital, to lodge the ampulla of the posterior semicircular canal, and the cerebral openings of two canals which enclose respectively the hind end of the external canal and the ventral end of the posterior canal. The dorso-posterior recess lies in the epiotic, is large, and has, in its ventro-posterior wall, a small opening which leads into the canal for the posterior semicircular canal, that canal traversing the epiotic. In Amia, the hind wall of the labyrinth recess is formed by an important cartilaginous ridge, membranous in its middle portion, which projects antero-mesially from the lateral cranial wall and separates the labyrinth recess from an important posterior portion of the cranial cavity which I described ('97, p. 703) as the postauditory or occipital chamber. If the membranous ear of Amia, and in particular the sacculus, were to be greatly developed, the labyrinth recess would have to be correspondingly enlarged, and this would necessarily push the posterior wall of the recess backward and mesially, the vagus foramen remaining always posterior to the wall. As the saccular recess was thus pushed backward it would split the dorsal edge of the basioccipital and the ventral edge of the exoccipital each into two parts, one of these parts forming the outer and the other the inner wall of the recess, and so give rise to a saccular groove on the dorsal surface of the former bone and to a mesial process, roofing that groove, on the internal sur-

face of the latter bone. The mesial process of the exoccipital of Scorpaena is, accordingly, a definite part of the cranial wall and not simply an ossification of the dura mater, as Sagemehl considered it to be ('84 b, p. 85). That part of the process that, in the Characinidae and Cyprinidae, is said by Sagemehl to roof the cavum sinus imparis may however be such an ossification; for this cavum lies in the cranial cavity itself, and not in the walls of that cavity, as the saccular recess does. The true internal, or cerebral surface of these two occipital bones of Scorpaena is accordingly formed by the mesial processes of the exoccipitals and by that small portion of the dorsal surface of the basioccipital that lies between those processes. The nervus glossopharyngeus first perforates the mesial, membranous wall of the labyrinth recess and then the outer, bony wall of the recess, as in Amia, traversing, in its course, a space that is hollowed out of the cranial wall to receive the ear and the ganglion of the nervus acusticus.

The anterior portion of the cranial cavity of Scorpaena is enclosed between the alisphenoids and the ventral flange-like processes of the frontals, and does not, in the adult, lodge any portion of the brain, the brain being small, relatively to the cranial cavity, and its anterior end reaching, approximately, only to the level of the hind edge of the basisphenoid. This part of the cranial cavity, in the dried skull, opens ventrally, by a relatively long and narrow median opening, into the hind end of the orbit, and this opening, bounded posteriorly by the basisphenoid, is the orbital opening of the brain case. In the recent state it is closed by the flaring dorso-posterior edge of the membranous posterior portion of the interorbital septum. Posterior to the hind edge of the basisphenoid, and extending approximately to the hind edge of the proötics, there is, in the recent state, when the brain is removed, a large, nearly round, pit-like depression, formed in the fatty and connective tissues that cover the floor of the cavity. This depression lodges the hypoaria, and has, near the anterior edge of its floor, a small saucer-like depression which lodges the pituitary body and overlies the pituitary opening of the brain case.

2. INFRAORBITAL CHAIN OF BONES.

The infraorbital bones are the three so-called suborbital bones of current descriptions, and a small postorbital bone, which latter bone has, so far as I can find, never been described.

The three so-called suborbital bones are, as is well known, firmly bound together to form a single rigid piece which extends backward across the cheek and abuts against and is firmly bound to the outer surface of the preopercular. The anterior one of these three bones, which I shall call the lachrymal, is an irregular five or six rayed bone, and is called by both Günther ('60) and Boulenger ('04) the preorbital. The several rays of this bone are of varying and unequal proportions, and their bases are connected, excepting between the dorsal and posterior rays, by thin webs of bone in which there may be additional smaller rays. The dorsal ray is a thick stout process, which is concave on its dorsal edge and there articulates with the large articular surface on the outer end of the horizontal arm of the ectethmoid. The anterior ray is a pointed process, and rests upon and is strongly bound by ligamentous tissue to the lateral (distal) portion of the dorsal surface of the ligamentary process of the maxillary. The posterior ray is a sharp or rounded process which fits against, and is rigidly bound to, the outer surface of the anterior end of the second bone of the series. Two of the remaining rays form two of the sharp spines characteristic of the fish, the one directed ventrally and the other antero-ventrally, from the ventral edge of the bone. The sixth ray, when present, lies in the web

of bone that unites the dorsal and anterior rays, and the anterior pore of the main infraorbital canal lies at the outer end of this ray, there opening on the external surface of the web of bone, close to its dorso-anterior edge. On the internal surface of the bone, opposite or slightly anterior to this latero-sensory opening, a stout ligament has its origin, and, running ventro-mesially, is inserted on the lateral surface of the dorsal edge of the maxillary process of the palatine, opposite and immediately anterior to the surface of insertion of the rostro-palatine ligament. On the ventral edge of the anterior ray of the bone, usually close to its base, and hence between it and the anterior one of the two ventral spines of the bone, is the opening of the second primary tube of the infraorbital canal; and on the ventro-posterior edge of the anterior ventral spine, is the opening of the third primary tube of the same canal. On the posterior edge of the posterior ventral spine, or on the ventral edge of the posterior ray of the bone, the position varying slightly, is the opening of the fourth tube; this tube lying between the lachrymal and the next posterior bone of the series. Along the internal surface of the posterior ray, the main infraorbital canal passes from the lachrymal into the second bone of the chain. The rays of the lachrymal bone thus, all but one, have relations to the primary tubes of the latero-sensory system. The bone lodges three sense organs of the infraorbital line.

The second infraorbital bone, is, in position, a first suborbital bone. It is an elongated bone, traversed by the main infraorbital canal, and has primary tubes of the line at either end. It lodges a single infraorbital sense organ and hence is a single latero-sensory skeletal unit. A short spine arises near the hind edge of the bone, and projects backward above the fifth infraorbital pore. This spine is hardly noticeable in young specimens of Scorpaena scrofa, or in either young or adult specimens of Scorpaena porcus.

The third infraorbital, or second suborbital, is, as Gill ('88) says, „hypertrophied and developed as a stay impinging on the anterior wall of the preopercular". It abuts against, and is firmly bound by tissue to, a depressed line on the anterior surface of the outer edge of a strongly developed ridge on the outer surface of the preopercular, opposite the base of the largest and most dorsal preopercular spine. The bone is convex externally and concave internally, and in the middle line of its external surface there is a longitudinal ridge which marks the position of the enclosed latero-sensory canal. Near the posterior end of this ridge, two primary tubes lead from the canal to the outer surface of the bone, one on the ventral surface of the ridge, and the other, slightly posterior to it, on the dorsal surface of the ridge; these tubes being, respectively, the 6 th. and 7 th. primary tubes of the line. The bone lodges two infraorbital sense organs. A short spine projects backward above the seventh infraorbital pore, this spine, like the one on the first suborbital, being unimportant in young specimens and in Scorpaena porcus.

The postorbital bone is a small semi-cylindrical piece of bone that lies in the dermis that forms the hind margin of the orbit, about midway between the dorsal edge of the third infraorbital bone and the postorbital corner of the skull. It lodges a single latero-sensory organ, and is developed in relation to that organ.

3. SUSPENSORIAL APPARATUS AND MANDIBLE.

The hyomandibular, symplectic, preopercular and palato-quadrate are all united or firmly bound together, and form a single piece which articulates with the skull at its anterior and posterior ends and bears the mandible.

QUADRATE.

The quadrate is a quadrant-shaped bone with its ventral corner thickened to form an articular surface for the mandible. The dorsal edge of the bone is wavy, and is bounded by cartilage which separates it from the ventral edge of the metapterygoid. Its anterior edge is nearly straight, is bevelled on its internal surface, and overlaps and fits against the external surface of the ventral limb of the ectopterygoid. Its posterior edge is slightly convex, is thickened and grooved, and fits against the anterior edge of the ventral portion of the preopercular. This thick posterior edge of the bone terminates dorsally in a short point, usually longer and sharper than in the specimen used for the figures. This point fits against the inner surface of a thin flange on the anterior edge of the preopercular, and between it and the dorsal edge of the body of the quadrate there is a curved notch. This notch forms the relatively wide dorsal end of a shallow and tapering groove on the inner surface of the bone, the groove running downward and forward to the thickened articular head of the bone, where it ends in a slight recess. The groove lodges the ventral three-fifths of the symplectic and may be said to separate the quadrate into two parts, a body and a posterior process. The groove is everywhere wider than that part of the symplectic that lies in it, a channel thus being left on either side of the latter element. At the upper end of the channel that lies anterior to the symplectic, there is a perforation of the apparatus, through which the mandibularis internus facialis passes from the outer to the inner surface of the palato-quadrate, and then runs downward in the channel along the inner surface of the apparatus. At the upper end of the channel that lies posterior to the symplectic, the mandibularis externus facialis passes, in a similar manner, from the outer to the inner surface of the apparatus, the arteria hyoidea traversing the same opening.

The posterior process of the quadrate of fishes is a feature of some morphological importance. It is not found, as a part of the quadrate, in the bony ganoids, but is found in most, if not all teleosts. It probably is present in all the Acanthopterygii and Anacanthini, for it is shown in all the figures that I can find of the quadrate of those fishes. In Siphonostoma, of the Lophobranchii, it would seem to be certainly present, though Supino's figure ('06) is not very definite in this particular. In Balistes, of the Plectognathi, I find it in normal position, and it is shown by Bruhl ('56) both in this fish and in Diodon. Among the Physostomi, of Günther's classification, it is shown in Belone (Swinnerton, '02), Esox (Swinnerton, '02), Galaxias (Swinnerton, '03), Salmo (Parker, '73), Hyodon (Ridewood, '04 b), Osteoglossum (Ridewood, '05 a), Megalops (Ridewood, '04 a), Alepocephalus (Gegenbaur, '78) and Notopterus (Ridewood, '04 b). In Ameiurus (Mc Murrich, '84), Silurus (Jaquet, '98) and Erythrinus (Sagemehl, '84 b) it seems to be present, in a modified form, as a short process that gives support to the lower end of the preopercular. In Carassius auratus, I find it as a short but normal process, a short groove here lodging a short terminal portion of the symplectic. In Ridewood's figures of the Mormyridae ('04 b) it seems to be wholly absent, as it does also in most of that author's figures of the Clupeoid fishes ('04 c); but Erdl ('47) apparently shows it in Gymnarchus, and I find it perfectly normal, though small, in Clupea harengus. In the Muraenidae, which I am investigating, I am of the opinion that both this process and the symplectic are indistinguishably fused with the quadrate, and it may be that this same fusion has taken place in other fishes where these two structures seem to be wanting. In Erythrinus Sagemehl says ('84 b, p. 92) that the symplectic and quadrate are so closely united that even the lines separating the bones are nearly lost, this evidently representing a stage in the complete fusion of these bones.

In the bony ganoids, as stated above, the process is not found as a part of the quadrate. It is, however, elsewhere represented in both Amia and Lepidosteus. In Amia, it has fused with the symplectic and forms an irregular articular head of that bone (Allis, 97 a, pl. 20, Fig. 4); while in Lepidosteus it is the preoperculum of Parker's ('82 b) descriptions, and the interoperculum of Collinge's ('93) descriptions. In Amia the relations are all too evident to leave any doubt as to this homology; and comparison of Lepidosteus with Amia leaves no doubt as to this latter fish. The bone, in Lepidosteus, is not properly shown by either Parker or Collinge; the important features omitted being that the bone has an articular head smaller but similar to that in Amia, and that this head articulates with a facet on the posterior surface of a ventrally projecting portion of the articular head of the quadrate. The disappearance of a relatively small intervening wall of quadrate bone, or a slight shifting of the parts together with a concomitant fusion of the bone with the adjoining symplectic, would produce the conditions found in Amia; while a fusion of the bone with the quadrate, instead of with the symplectic would produce the usual teleostean quadrate. A further fusion of the symplectic with the quadrate would apparently produce the conditions found in the Siluridae and those others of the Physostomi in which the process of the quadrate seems absent; thus leaving only the Lophobranchii as apparent exceptions to the general rule. The bone would seem to be, judging from the conditions found in Lepidosteus, a branchiostegal ray related either to the quadrate or to the mandible.

In Polypterus this process of the quadrate is neither shown nor described, so far as I can determine, and in this fish there is also, according to Traquair ('70), no symplectic.

It may here be stated that Gymnarchus, in the fusion of the symplectic, the posterior process of the quadrate and the body of the latter bone into a single piece, and in the intimate and rigid nature of the attachment of the entire suspensorial apparatus to the cranium, approaches the amphibian condition, as it does also, as I ('04) have lately shown, in the possession of an auditory apparatus resembling the amphibian ear.

METAPTERYGOID.

The metapterygoid consists of a thick quadrant-shaped endosteal portion, and three thin but extensive flanges that appear to be of purely membrane origin. The curved ventral edge of the quadrant-shaped portion is directed ventro-anteriorly and is everywhere bounded by cartilage, a narrow band of which separates it from the dorsal edge of the quadrate. The angle of the quadrant is directed dorsally, and this angle is apparently the centre of ossification for the endosteal body of the bone and also for the apparently membrane flanges. From this angle a slender process arises, and projects dorso-anteriorly in the line prolonged of the hind edge of the body of the bone. This process is more than one half as long as the hind edge of the bone, and has the same general appearance and color as the body of the bone. It may, therefore, also be of endosteal and not of membrane origin. One of the three membrane flanges is a thin web of bone that fills the angle between the anterior edge of this slender process and the dorso-anterior edge of the body of the bone. The other two flanges arise from the full length of the hind edge of the bone, that hind edge including the slender process as well as the body of the bone. The two flanges project dorso-posteriorly, and, spreading somewhat, enclose between them a V-shaped space. This space lodges and gives insertion to a deeper portion of the levator arcus palatini, the superficial portion of that muscle lying external to the external flange. The V-shaped space also lodges that terminal portion of the external carotid

that runs downward and backward to fall into the arteria hyoidea, as already described. The hind edge of the external one of these two flanges abuts against, and is firmly bound to, the anterior edge of the ventral half of the shank of the hyomandibular, the dorsal portion of the corresponding edge of the internal flange being similarly connected with, but not abutting against, the anterior edge of that thin portion of the hyomandibular, apparently of membrane origin, that lies between the anterior articular process and the shank of the bone. The external flange is quite undoubtedly an ossification of the metapterygoid membrane of Amia, the thickened, process-like portion of the flange being the homologue of the metapterygoid process of that fish (Allis, '97, p. 557).

Across the anterior one third to two-thirds of the internal surface of the body of the metapterygoid, at about the middle of its length, the entopterygoid extends, that bone lying at an angle to the metapterygoid. The V-shaped space between the two bones is filled by, and gives insertion to, a portion of the adductor arcus palatini.

ECTOPTERYGOID.

The ectopterygoid is a slender bone, with two sharply pointed limbs lying at an obtuse angle to each other. From the angle between the two limbs a thin and irregular process projects dorso-posteriorly, lying against the internal surface of the palato-quadrate cartilage, and, beyond that cartilage, against the internal surface of the metapterygoid. The ventro-posterior limb of the bone is the shorter of the two, is bevelled and fits against the internal surface of the anterior edge of the quadrate. The dorso-anterior limb fits upon the dorsal edge of the posterior portion of the ventral, ectosteal flange of the palatine, and although but a thin and slender bone is grooved its full length, on its dorsal surface. This little groove lodges the ventral edge of a slender and rod-like portion of the palato-quadrate cartilage, which connects the cartilages of the palatine and quadrate regions, and, mesial to that rod of cartilage, lodges the ventro-lateral edge of the anterior portion of the entopterygoid.

ENTOPTERYGOID.

The entopterygoid is a V-shaped bone, one limb of the V being small and the other large, the point of the V directed ventro-laterally. The small lateral limb lies against the internal surface of the anterior portion of the metapterygoid, and against the same surface of the adjoining portion of the palato-quadrate cartilage. The larger mesial limb is a thin smooth and delicate, but relatively large plate of bone, the ventral edge of the anterior portion of which lies in the groove on the dorsal surface of the dorso-anterior limb of the ectopterygoid, and there rests against the inner surface of the palatine bone and the same surface of the rod-like remnant of the palato-quadrate cartilage. Posterior to the latter cartilage, the ventral edge of this plate rests against, and is bound by tissue to, the internal surface of the metapterygoid. This mesial limb of the entopterygoid is closely applied to the ventral surface of the anterior portion of the adductor arcus palatini muscle, and its dorso-mesial edge is connected, by the lining membrane of the mouth cavity, with the ventral surface of the parasphenoid.

The adductor arcus palatini has, as already stated, a long surface of origin, this surface beginning on the lateral surface of the ascending process of the parasphenoid and on adjacent portions of the proötic and from there extending forward along the lateral surface of the body of the parasphenoid as far as the antorbital cartilage. From this long surface of origin the broad muscle runs

latero-ventrally and has a correspondingly long surface of insertion on the palato-quadrate. The ventro-lateral edge of this surface of insertion forms a long line which begins anteriorly at the anterior end of the mesial plate of the entopterygoid, extends the full length of the line of attachment of that plate to the palatine, ectopterygoid and metapterygoid, lying in the V-shaped space between the two limbs of the bone, and then, beyond the entopterygoid, crosses the inner surface of the metapterygoid to the hind edge of the body of that bone. There it turns upward along the hind edge of the internal one of the two membrane flanges on the hind edge of the metapterygoid, crosses onto the inner surface of the thin web of bone that fills the angle between the anterior articular head and the shank of the hyomandibular, and turning dorso-anteriorly follows the line of origin of that web its full length. The muscle thus has its insertion partly on the hyomandibular, but mainly on the palato-quadrate.

PALATINE.

The palatine contains endosteal and ectosteal components, indistinguishably fused. The endosteal component forms the thickened body of the bone, and its curved, relatively long and rod-like anterior end. The ectosteal component is a plate-like portion which projects ventro-laterally from the ventral edge of the endosteal component. The anterior portion of this ectosteal component is thicker than its posterior portion, and the ventral edge of this thickened anterior portion is garnished with small villiform teeth. The curved, anterior, rod-like portion of the bone is capped with cartilage, articulates with the dorsal surface of the maxillary, as already fully described, and is the maxillary process of the bone. At the base of this maxillary process there is a small but sharp transverse ridge, the anterior surface of which is capped with cartilage and articulates with the inferior surface of the anterior palatine process of the ethmoid cartilage. Immediately anterior to this articular process of the palatine, on the dorso-mesial surface of the maxillary process of the bone, a little flattened surface gives insertion to the rostro-palatine ligament. Directly opposite this little surface, on the dorso-lateral surface of the bone, a similarly flattened surface gives insertion to the ventro-mesial end of the lachrymo-palatine ligament. On the mesial surface of the body of the bone, on a ridge that lies immediately postero-ventral to the base of the maxillary process, the strong broad vomero-palatine ligament has its insertion; the ligament running antero-mesially to its surface of origin on the ventral surface of the vomer.

Posterior to the base of the maxillary process, the body of the palatine expands rapidly and soon ends abruptly, this part of the bone being somewhat demicone-shaped, with its flat surface presented ventro-mesially. Its hind end connects by synchondrosis with the anterior end of a block of cartilage that corresponds to the middle cartilaginous remnant of my descriptions of the palato-quadrate of Scomber. This cartilage falls away rapidly, posteriorly, and soon becomes a rod-like and frequently imperfect and discontinuous piece of cartilage which extends backward from the ventro-lateral portion of the hind end of the body of the palatine. Against the flat ventro-mesial surface of this cartilage, and against the corresponding surface of the hind end of the body of the palatine, anterior to it, the anterior end of the entopterygoid rests.

The hind end of the body of the palatine, together with the cartilage immediately posterior to it, forms a pronounced tranverse ridge on the dorso-lateral surface of this part of the palato-quadrate apparatus, near its dorso-mesial edge. The dorso-anterior surface of this ridge, a surface formed partly of bone and partly of cartilage, articulates with the articular surface at the mesial

end of the curved ventral edge of the arm of the ectethmoid. The articular ridge accordingly forms the posterior ethmoid articular surface of the palatine. Its summit, which is wholly cartilaginous, gives insertion to the strong ethmo-palatine ligament, which ligament is usually double and has its origin on the posterior, orbital surface of the ectethmoid.

HYOMANDIBULAR.

The hyomandibular is an irregular cross of primary bone, with the cross-piece placed obliquely across the shank, and with the four angles between the cross-piece and the shank filled by thin webbing laminae of what is apparently membrane bone.

The dorsal end of the shank of the cross forms the posterior articular head of the bone, this head articulating with the pterotic. The cross-piece has articular heads at either end, the posterior one articulating with the opercular, and the anterior one with the articular facet on the sphenotic and proötic. The thin web of bone that fills the angle between the two cranial articular heads of the bone is frequently perforated by a large foramen, due to the wear, against its inner surface, of that process of the proötic that gives origin to certain of the levator muscles of the branchial arches. A relatively tall ridge of bone begins at the point where the cross-piece crosses the shank of the bone, and runs downward and backward on the external surface of the shank. The dorsal end of the preopercular fits against the hind surface of this ridge, and also against the outer surface of the hyomandibular posterior to the ridge, the dorsal end of the preopercular projecting dorsally across the opercular arm of the hyomandibular, and there leaving a space between itself and that bone. Through this little space, that small superficial portion of the dilatator operculi muscle that arises in the dilatator fossa passes, the remaining and larger portion of the muscle having its origin from the preopercular and from the external surface of the hyomandibular internal to and posterior to that bone.

The ventro-anterior edge of the web of bone that fills the space between the anterior articular arm and the shank of the hyomandibular is bound by a wide but strong band of fibrous tissue to the dorsal portion of the internal one of the two posterior, membrane flanges of the metapterygoid. Ventral to this latter flange, and ventral also to the related web of bone on the hyomandibular, the ventral half of the external one of the two metapterygoid flanges abuts against and is firmly bound by tissue to the anterior edge of the shank of the hyomandibular. At the ventral edge of this latter flange, between the metapterygoid, the hyomandibular and the hyomandibulo-symplectic interspace of cartilage, there is an oval space which transmits the arteria hyoidea.

The ventral end of the shank of the hyomandibular is in synchondrosis with the symplectic, the two bones being separated by a relatively large interspace of cartilage which gives articulation, on its postero-internal surface, to the small and rod-like interhyal. The interhyal lies, in its position of rest, in the line produced of the shank of the hyomandibular; lying internal to the preopercular and interopercular, and being bound by fibrous tissues to both those bones, the attachment to the interopercular being particularly strong.

The facialis canal through the hyomandibular enters the bone by a large pit-like opening on its internal surface, this opening lying in the endosteal part of the bone, close to the angle between the anterior articular arm and the shank of the bone. From this pit two canals arise. One runs downward in the shank of the bone, opens on its outer surface, anterior to the ridge that gives support to the preopercular, and transmits the truncus hyoideo-mandibularis facialis. The other runs downward and backward and separates into two parts, one of which opens on the outer surface of

the hyomandibular in the angle between the opercular arm and the shank of the bone, and the other close to the hind edge of the web of bone that fills the space between the same two arms of the bone. This second and branching canal transmits the two branches of a nerve that supplies the two dorsal latero-sensory organs of the preopercular canal.

The ramus hyoideus separates from the truncus hyoideo-mandibularis as that nerve reaches the external surface of the hyomandibular, passes downward and backward through a small passage between the hind edge of the hyomandibular and the anterior edge of the preopercular, and so reaches the internal surface of the latter bone.

SYMPLECTIC.

The symplectic is a slender curved bone, the dorsal two-fifths of which lie along the hind edge of the cartilage that separates the metapterygoid and quadrate, while the ventral three-fifths lie in the symplectic groove on the internal surface of the quadrate. The ventral end of the bone is tipped with cartilage. Its dorsal end is bounded by the interspace of cartilage that lies between itself and the hyomandibular. This interspace of cartilage is in close contact with the hind edge of the palato-quadrate cartilage, but is not continuous with that cartilage. A part of the hind edge of the interspace of cartilage is overlapped externally by a thin web of bone on the anterior edge of the preopercular, near the middle of its length, and the hind edge of this part of the cartilage bears the articular facet for the proximal end of the interhyal. Between the hind edge of the dorsal portion of the symplectic, anteriorly, and the anterior edges of the preopercular and the posterior process of the quadrate posteriorly, there is a long oval space which transmits the ramus mandibularis externus facialis and the arteria hyoidea. Along the anterior edge of the symplectic, between it and the hind edge of the dorsal portion of the body of the quadrate, there is a small opening which transmits the ramus mandibularis internus facialis.

PREOPERCULAR.

The preopercular is a curved bone, traversed its full length by the preopercular latero-sensory canal. It has, on its hind edge, five so-called spines, the two ventral ones being blunt or pointed eminences, rather than spines. The dorsal spine is by far the longest and is always double, a small spine, almost completely fused with it, arising on the external surface of its base. At the ventral edge of the base of this small spine, and hence on the external surface of the base of the large spine, there is the opening of a primary latero-sensory tube; and similar openings are found at the ventral edges of each of the three next distal spines. The fifth spine lies at the distal end of the bone, is an eminence rather than a spine, and immediately distal to it there is a primary tube which arises from the sensory canal as it passes from the preopercular into the mandible. The spines, thus here, as on the lachrymal, have definite relations to the primary tubes of the latero-sensory system; but there is not a spine for every tube, for dorsal to the most dorsal spine there is, in the preopercular, still another opening of the latero-sensory canal, but without related spine. The bone lodges six latero-sensory organs, one between each two adjoining tubes.

At the middle of the anterior edge of the preopercular, spanning the hollow of the curve of the bone, there is a thin web of bone which bears, on its internal surface, a small cup-like depresion, this depression receiving the lateral surface of the proximal articular head of the interhyal and to that extent forming part of the articular cup for that element. Lateral to this web of bone, or

slightly dorsal to it, on the raised and ridge-like external surface of the preopercular, there is a shallow groove which marks the line of insertion of the hind end of the third bone of the infraorbital chain.

OPERCULAR BONES.

The three opercular bones have the shapes shown in the figures. On the external surface of the opercular, three pronounced ridges radiate from the articular facet of the bone. One of these ridges forms the ventral edge of the bone, which edge is presented anteriorly and but slightly ventrally; the other two ridges lying on the dorsal portion of the bone and both of them terminating in free spines. The internal surface of the bone, dorsal to the dorsal one of the three spinous ridges, is depressed, and in this depression the adductor operculi has its insertion; the thin and almost membranous levator operculi being inserted along the dorsal edge of the bone. The deep indentation in the hind edge of the bone, between the two dorsal spines, corresponds to the indentation, without related spines, in the hind edge of the bone of Scomber.

The angular-shaped subopercular overlaps internally, and embraces the ventral corner of the opercular, extending upward one half to two-thirds the length of its anterior edge, but along its entire posterior edge; usually projecting upward slightly beyond the dorsal edge of the bone. It is a thin, flat bone, its long dorso-posterior arm, in particular, being so thin that it is flexible and easily torn.

The dorso-posterior edge of the interoperculum is slightly concave, and lies in a nearly horizontal position. The posterior corner of this edge slightly overlaps externally, and is strongly bound by tissue to the ventral corner of the subopercular, while the anterior corner lies external to the interhyal, and is strongly bound to it by tissue. The lateral surface of the ventral half of the interhyal here fits into a large but shallow depression on the internal surface of the interopercular, this depression having a raised dorsal edge which gives it the appearance of an articular facet. The interopercular is thus here related to the interhyal somewhat as the branchiostegal rays are to the ceratohyal, suggesting it being such a ray. Between its concave postero-dorsal edge and the anterior edge of the subopercular there is a large triangular space, spanned by a sheet of tough fibrous tissue which connects the bones. The ventral end of the interopercular is directed antero-ventrally and gives attachment to a short strong ligament which has its origin on the hind end of the angular.

In Phractolaemus Ansorgii, Ridewood says ('05 a, p. 279) that the interopercular is traversed by a portion of the preopercular latero-sensory canal, adding that this is the only instance of the kind known to him. If the section of canal enclosed in the bone lodges a latero-sensory organ, the bone can not be a simple interopercular.

MANDIBLE.

The mandible has, on its outer surface, a large rounded longitudinal ridge which extends from the ventral edge of the articular facet for the quadrate forward across the articular and then across the dentary, nearly to the anterior end of the latter bone. On the inner surface of the articular and dentary there is a corresponding hollow, which lodges, in its ventral portion, the rod-like Meckel's cartilage. Immediately ventral to the ridge, the mandibular latero-sensory canal traverses the dentary and articular, entering the dentary near its anterior end and leaving the articular at the base of the process that forms the posterior half of the articular facet for the quadrate. The

dentary lodges four organs of the sensory line and the articular, one. Primary tubes leave the canal at either end of the angular, and four tubes leave it as it traverses the dentary, one of these tubes being the anterior terminal tube of the line.

The dentary has the usual dorsal and ventral limbs, separated by a deep V-shaped reëntrant angle. The dorsal edge of the dorsal limb is lined its full length with villiform teeth. Immediately ventral to this edge, on the outer surface of the bone, and at about the middle of its length, there is a large and deep depression which lodges and gives insertion to the base of a tapering gristly structure which projects posteriorly and forms the core of the mandibular labial fold. This gristly, semi-cartilaginous structure is attached, at its hind end, by dermal tissues to the inner surface of the hind end of the maxillary, and would seem to be the homologue of the labial cartilage of Swinnerton's descriptions of Gasterosteus.

The angular is a small bone which forms the postero-ventral corner of the mandible. Its dorsal end is united by synchondrosis with the articular, immediately ventral to the articular facet for the quadrate, a small interspace of cartilage here being visible on the inner surface of the mandible. The angular gives insertion to a short but strong ligament which has its insertion on the ventral end of the interopercular, and also gives insertion to certain of the ligamentous articular tissues that bind the mandible to the quadrate. There is, as in Scomber, no evident ligamentum mandibulo-hyoideum.

The articular has a stout coronoid process, the base of which forms the anterior portion of the articular facet for the quadrate. The dorsal end of the process lies slightly postero-ventral to the hind end of the dorsal limb of the dentary, and the two bones are here connected by a pad-like structure of tough fibrous tissue which extends forward a short distance along the lateral and dorsal surfaces of the hind end of the dorsal limb of the dentary. This pad forms, in the recent state, a pronounced feature of the mandible, and the inner surface of the maxillary slides against it as the mouth is opened and closed. The maxillo-mandibular ligament, as already described, runs across the external surface of this pad of tissue, with apparent interchange of fibers, and has its attachment to the external surface of the base of the coronoid process and the adjoining portions of the articular. On the hind edge of the articular a stout curved process, projecting dorsally, forms the posterior half of the articular facet for the quadrate. The dorsal end of this process gives insertion to a short stout ligament which extends anteriorly and has its origin on the adjacent lateral edge of the articular head of the quadrate. The mesial or postero-mesial surface of the process is smooth and slightly convex, is covered with a thin layer of fibrous or fibro-cartilaginous tissue, and, when the mouth is opened and shut, slides upon a part of the hind edge of the quadrate immediately dorso-posterior to the articular head of that bone; the outer, dorso-posterior end of the process finally abutting against a part of the quadrate, and so limiting the opening movement of the mandible. This sliding articulation of this process of the articular is with the posterior process of the quadrate, and not with the body of that bone, and manifestly recalls the mandibulo-symplectic articulation of Amia, to which reference was made when describing the quadrate. In Scomber a similar sliding articulation doubtless exists, but, when describing that fish ('03, p. 157) I did not recognize it, or its probable homology.

On the internal surface of the articular, the hind end of Meckel's cartilage is continued backward, for a short distance, as a bony ridge which presents the appearance of a posterior and ossified continuation of that cartilage. On the dorsal surface of this ridge, and partly immediately anterior to it, the tendon of the deeper part of the adductor mandibulae has its insertion.

4. ADDUCTOR MANDIBULAE AND LEVATOR ARCUS PALATINI MUSCLES.

The adductor mandibulae is completely separated into dorsal and mandibular portions. The dorsal portion is a large muscle, almost completely separated into two divisions, a superficial and a deeper one. The superficial division is apparently the homologue of the muscle A_1 of Vetter's descriptions of other teleosts, the deeper division representing the two muscles A_2 and A_3 of the same descriptions. The mandibular portion of the muscle is the muscle A_ω of Vetter's nomenclature, and lies wholly in the mandible. The mandibular branch of the nervus trigeminus, in its course to enter the mandible, passes between the muscles A_1 and $A_2 A_3$.

The muscle A_1 arises from the outer edge of the preopercular, there lying, in its dorsal portion, directly external to the levator arcus palatini, and in its ventral portion directly external to a portion of $A_2 A_3$. The fibers of the dorsal two-fifths, approximately, of the muscle do not reach the preopercular, being inserted on a broad thin tendinous band which crosses the outer surface of the levator and has its insertion on the preopercular. The fibers of the muscle all run forward in a nearly parallel course, and are inserted on a tendinous band that extends the full length of the anterior edge of the muscle. The dorsal end of this band becomes a short stout tendon which has its insertion on the mesial surface of the shank of the maxillary, the ventral end of the band joining the tendon of the muscle $A_2 A_3$. The anterior edge of the tendinous band gives attachment to the fibrous tissues that line the lateral surface of the mucous membrane that extends from the ventral edge of the palato-quadrate to the internal surface of the maxillary, and it is in this fibrous tissue that the maxillo-mandibular ligament, already described, has its course, lying close along the anterior edge of the muscle A_1. This maxillo-mandibular ligament must accordingly be acted on by the muscle A_1, and hence serves in part as its tendon of insertion; a contraction of the ventral fibers of A_1 rotating the maxillary. In Scomber the tendon of A_1 is inserted on the internal surface of the lachrymal, the maxillo-mandibular ligament in part giving insertion to the deeper portion, A_3, of the adductor (Allis, '03, p. 192).

The muscle $A_2 A_3$ is much thicker and stouter than A_1, and has its origin on the external surface of the body of the metapterygoid, near its hind edge, and, ventral to the metapterygoid, on the anterior surface of the preopercular. The muscle is incompletely separated into dorso-internal and ventro-external portions which may represent A_3 and A_2 respectively, the fibers of A_3 all passing internal to the external bundle of the levator arcus palatini, while the fibers of A_2 pass external to or lie wholly ventral to that muscle. The fibers of both portions of the muscle at first converge slightly forward, and then contract rapidly, and are all, or nearly all inserted on a large tendon which passes into the mandible. The few fibers that are sometimes not so inserted form a broad, thin superficial sheet, the fibers of which separate from the deeper fibers of the muscle and have their insertion in a tendinous formation on the inner surface of the muscle A_1. The large tendon $A_2 A_3$ separates into three parts. The middle one of these three parts arises mainly in relation to the fibers of A_3, the other two arising mainly in relation to the fibers of A_2 and A_1 these two tendons lying the one postero-ventral and the other antero-dorsal to the middle tendon. The middle tendon runs downward and forward, and has its insertion on the mesial surface of the articular immediately dorsal to the hind end of Meckel's cartilage. The postero-ventral tendon runs forward and downward across the lateral surface of the middle tendon, and then turns rather sharply downward, passes

across the mesial surface of the hind end of Meckel's cartilage and is inserted on the mesial surface of the articular ventral to the cartilage. The antero-dorsal tendon turns forward and is inserted on the tendinous formation that covers the mesial surface of A_ω.

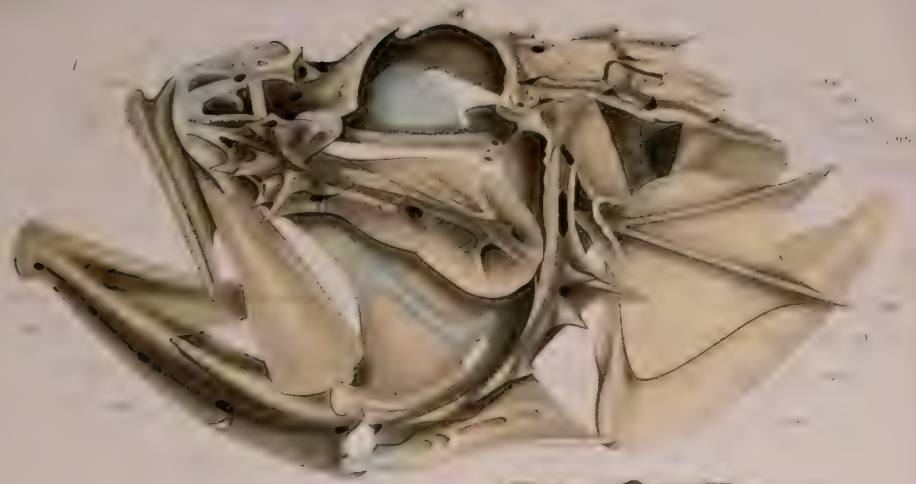
The mandibular portion, A_ω, of the adductor muscle, arises wholly on the mesial surface of the mandible, its fibers converging toward and having their insertions on a tendinous formation which largely covers the mesial surface of the muscle. A part of the fibers of this tendinous formation are collected and separated to join the antero-dorsal tendon of A_2A_3, the remaining fibers running directly backward, mesial to all the tendons of the muscle, and having their insertions, as a broad tendinous band, on the preopercular, near its ventral end. In Scomber this latter tendon is inserted by two heads, one on the preopercular and the other on the quadrate, the rami mandibularis externus and internus passing between the two heads of the tendon (Allis, '03, p. 194).

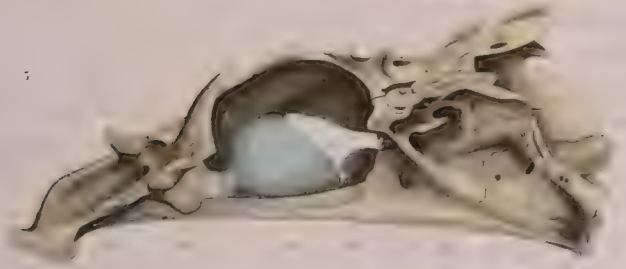
The levator arcus palatini arises from the roughened lateral corner of the sphenotic. Running downward from there, and spreading slightly forward and backward, it separates into superficial and deeper portions. The superficial portion passes internal to the superficial division, A_1, of the adductor mandibulae, between it and A_3, and then between A_2 and A_3, and has its insertion on the external one of the two flanges on the hind edge of the metapterygoid, and on adjacent portions of the hyomandibular and preopercular. Some of its fibers are also apparently inserted in the membrane that covers the external surface of the muscle A_3. A strong tendon is imbedded in this superficial portion of the levator, extends from the sphenotic to the metapterygoid, and gives insertion or origin to certain of the fibers of the muscle. The deeper portion of the muscle passes between the two flanges on the hind edge of the metapterygoid and has its insertion on those flanges and on the two membranes that connect the flanges with the anterior edge of the hyomandibular. The ventral end of the internal one of these two membranes has a strong attachment to the internal surface of the dorsal end of the interhyal, and it would seem as if the muscle must have some action on that bone. The two portions of the levator correspond respectively to the superficial and deeper portions of the muscle of Amia.

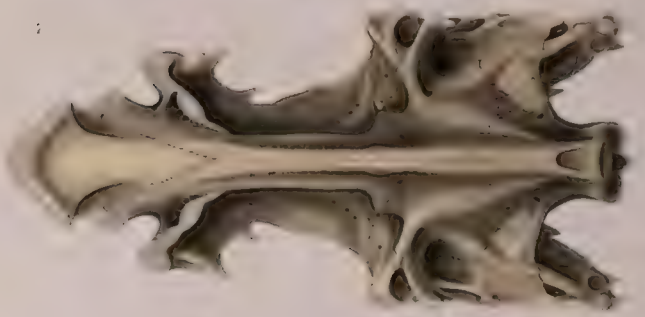
5. LATERO-SENSORY CANALS.

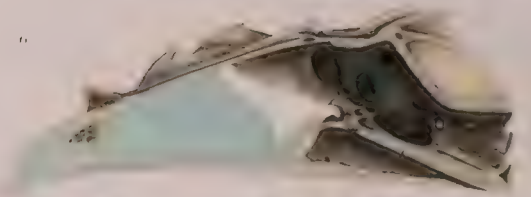
The primary tubes of the latero-sensory canals of Scorpaena, in every case examined, leave the bones to which they are related as simple and single tubes, but, in the overlying dermal tissues, most of them branch repeatedly giving rise to large and often complicated dendritic systems which open on the outer surface by small and often numerous pores. Certain of these dendritic systems, belonging to different canals, interanastomose, thus secondarily connecting primarily independent canals, and giving rise to conditions that might, in a superficial examination, be considered as marked irregularities in the course of those canals.

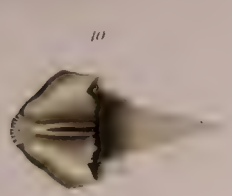
The main infraorbital canal begins at a group of pores that lies ventro-lateral to the interval between the two nasal apertures. In the two specimens that were carefully examined in this connection, this group was subcircular in outline and contained from 15 to 18 pores; and on one side of one of these two specimens certain of the pores of the group seemed to have anastomosed with certain pores of the second dendritic system of the supraorbital canal, thus apparently establishing a communication between those two canals, the communicating canal passing between the nasal apertures. The group of pores belongs to the first dendritic system of the line, and the trunk of the system enters







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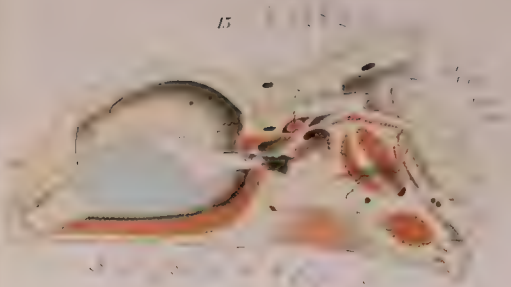
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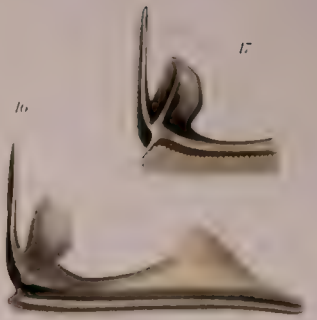
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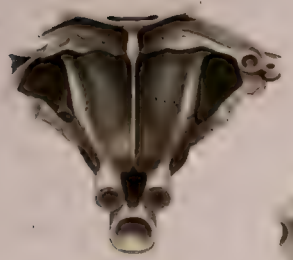
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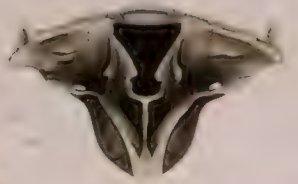
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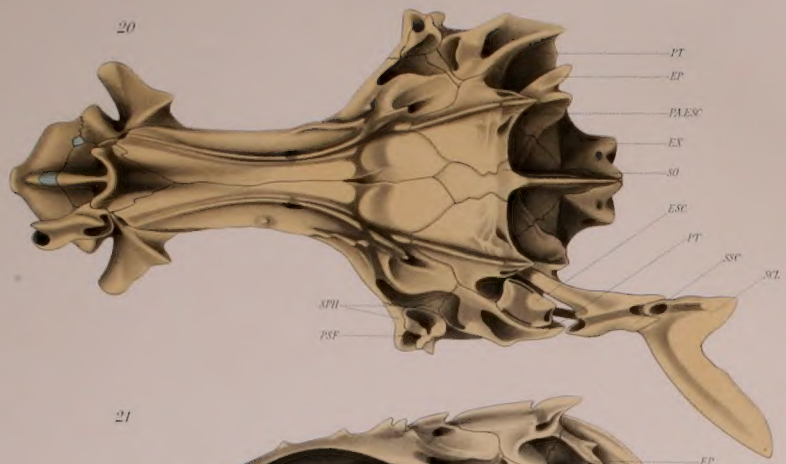

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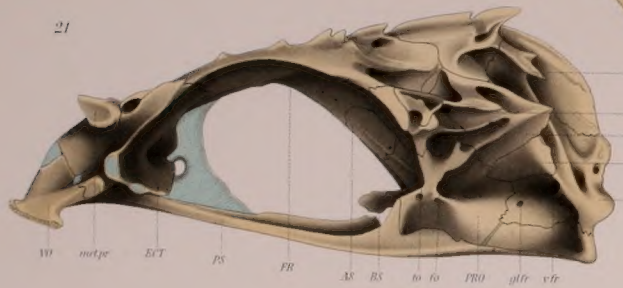

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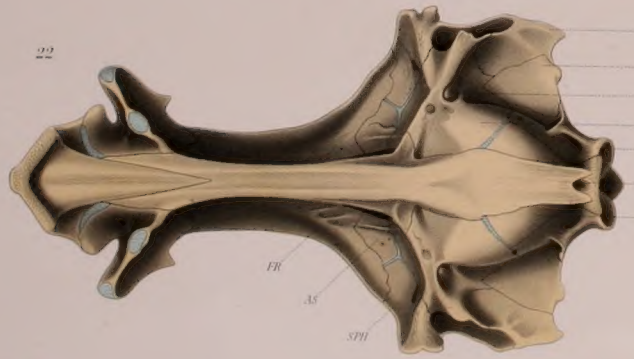

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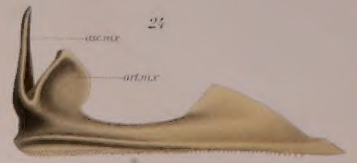

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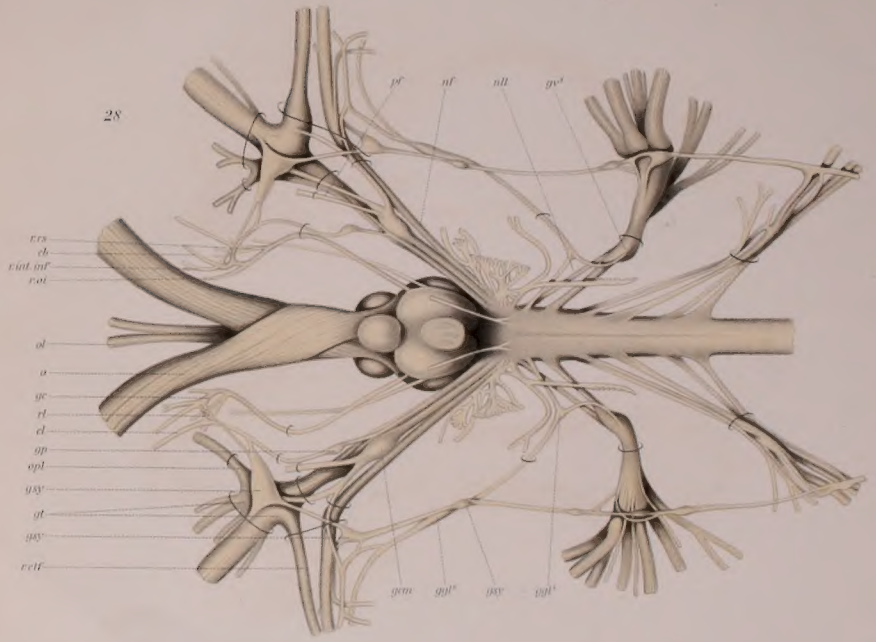

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